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22nd ONTARIO INDUSTRIAL WASTE CONFERENCE

JUNE 15-18, 1975
TORONTO, ONTARIO

PROCEEDINGS

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1975
MOE

Ministry
of the
Environment

Hon. George A. Kerr, Q.C.,
Minister

Everett Biggs,
Deputy Minister.

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P R O C E E D I N G S
OF THE
22ND ONTARIO INDUSTRIAL WASTE
CONFERENCE

HELD AT
THE PRINCE HOTEL, TORONTO, ONT.

JUNE 15 - 18, 1975

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Ontario Industrial Waste Conference 1975

P R E F A C E

K. H. SHARPE
Assistant Deputy Minister
Environmental Assessment & Planning
Ministry of the Environment
and
Chairman
Ontario Industrial Waste
Conference Planning Committee



With the production and distribution of the Proceedings from the 22nd Ontario Industrial Waste Conference, we conclude our activities for 1975. This year's edition includes the technical papers presented at the Conference, plus a summary abstract at the commencement of each paper, and reproduction of all or the pertinent graphs, slides and charts that were projected in conjunction with the presentation.

The 1975 Ontario Industrial Waste Conference was our most successful ever. There were 495 persons involved in the functions of the overall program. This included 385 registered delegates, 30 program participants and session chairmen, 70 spouses and 10 on the Conference support staff and committee.

The general consensus, and appreciated comments from those attending the Conference, was that the subject areas covered, the papers presented, the communications exchange between the speakers and delegates provided an ideal forum for mid-'70 industrial waste problems. I do wish to thank especially the speakers for the obvious time and trouble they took in the preparation of their papers. Each subject was presented interestingly, and shed new light or another aspect on waste problems and solutions that have plagued industry ever since our environmental consciousness has been aroused. The combination of thought-provoking papers, and the bridging by the session chairmen, decidedly contributed to a well-rounded program.

The Ontario Ministry of the Environment feels privileged to be able to host this annual Conference. Over the past twenty-two years we have seen it grow from a water-oriented program to embrace all aspects of pollution abatement and control. The introduction of such subject areas as environmental assessment, public participation, air management and the health aspects makes the Conference sufficiently comprehensive to be of interest to all those wishing to obtain new insight into today's complicated environmental concerns. As a matter of fact, the Ontario Industrial Waste Conference is the only forum available in Canada covering all avenues.

I would be remiss if I did not extend my thanks to the Conference Planning Committee members and support staff for their involvement. Without their interest and dedication, the Conference would never have been so successful. Should you require any additional information on the Conference, please contact the O.I.W. Conference Planning Committee, 135 St. Clair Ave., West, Toronto M4V 1P5, Ontario.

For your information the 23rd Ontario Industrial Waste Conference will again be held at The Prince Hotel in Toronto, June 13 - 16, 1976, inclusive. We invite all delegates to this year's Conference to attend the 1976 session.

A. N. Sharpe
Conference Chairman

1975 Conference Planning Committee Members



M.F. Cheetham
Co-ordinator



D.P. Caplice
Program Convenor

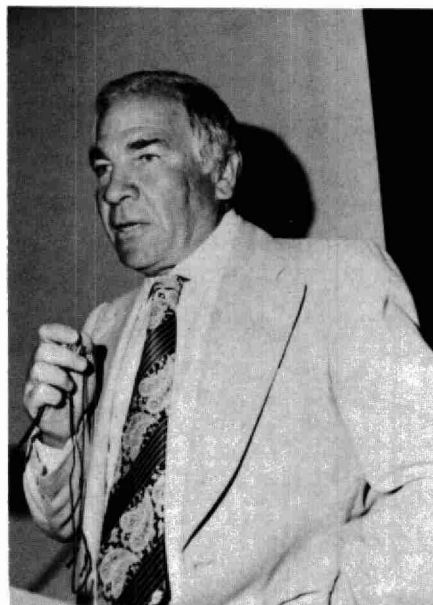


J.B. Patterson
Program Convenor

P R I N C I P A L S P E A K E R S

INDUSTRIAL WASTE CONFERENCE 1975

Mr. Biggs, Deputy Minister of The Ministry since February 1972, opened the Conference by showing a pictorial slide presentation of the functions of the various Branches making up the re-organized Ministry of the Environment.



EVERETT BIGGS

Deputy Minister

Ministry of the Environment



PAUL HENDERSON

President, R.G. Henderson & Son Ltd.

Toronto

Mr. Henderson was the well-received guest speaker at the Conference banquet. A world title-holding sailor and member of the 1976 Olympic organizing committee for sailing, he re-counted his experiences at previous Olympiads with several of his anecdotes involving world-renowned figures.

S E S S I O N C H A I R M E N

INDUSTRIAL WASTE CONFERENCE 1975

SESSION I

Mr. Harvey Clare
Environmental Protection Co-ordinator
Imperial Oil Limited
Toronto, Ontario
(Papers 1, 2, 3)



SESSION II

Mr. Wm. (Bill) F. Fell
Director, Environmental Control
The Ontario Paper Company Ltd.
St. Catharines, Ontario
(Papers 4, 5, 6)

SESSION III

Mr. Edward Formanek
Manager of Engineered Systems
Wheelabrator Corp. of Canada Ltd.
Oakville, Ontario
(Papers 7, 8, 9)



SESSION IV

Dr. James R. Kramer
Professor Geology
McMaster University
Hamilton, Ontario
(Papers 10, 11, 12, 14)

SESSION V

Mr. Wm. (Bill) J. Anderson
Commissioner of Public Works
Regional Municipality of Peel
Bramalea, Ontario
(Papers 13, 15, 16, 17)



PUBLIC PARTICIPATION IN LOCATION OF POWER LINES

The people affected by a new power line expect to have an opportunity to express their views on the need for, and the location of the line. The elements that are essential to a successful series of public hearings are: First, a carefully prepared, simple and readily understandable study of the entire area affected and of the environmental, social and economic impact of alternative routes. Second, an advocate to support and defend the selection of one of these alternatives. Third, an adequately large, representative and continuing audience. Fourth, procedures and an atmosphere at the hearing that discourages adversary attitudes and encourages lively discussion.

by

DR. OMOND M. SOLANDT

C.C., O.B.E., M.A., M.D., D.Sc.,
LL.D., D.Eng., F.R.C.P., F.R.S.C.



Born in Winnipeg, Dr. Solandt earned his degree in Medicine in Toronto, Cambridge and London, England. He founded the Medical Research Council's Physiological Laboratory at the Armoured Fighting Vehicle School at Lulworth in 1941 and was actively engaged in research. In 1942 he turned from medical research to operational research and formed the Armoured Fighting Vehicle Section of the Army Operational Research Group. He was a member of a mission to evaluate the effects of the atomic bomb in Japan. The years following the war, as Chairman and Director, he governed research for the Defence Research Board and Council, C.N.R., de Havilland Aircraft of Canada, Ltd., Hawker Siddeley Canada Ltd., DFC Systems Limited, The Science Council of Canada & Electric Reduction Company. In June 1972 he was appointed Chairman of the Solandt Commission for the investigation of the best location for Hydro corridors.

PUBLIC PARTICIPATION
in the
LOCATION OF POWER LINES

by

Dr. O. M. Solandt

I have been asked to speak about the problems of public participation in the location of power lines. I have just completed three years of hearings on two major bulk power transmission lines, one from Nanticoke to Pickering, the other from Lennox, which is quite close to Kingston, to Oshawa. These hearings have involved all the current aspects of public participation. I will not talk about the entire process but just about the public hearing part of the participation. I think Mr. O'Connor will make clear in the next talk that this is only a part of the process and that there is inevitably an essential prelude in which an effort is made to educate the public. This was done in both the cases I have dealt with, but I was personally less involved in the preliminary education process than in the actual hearing process. None the less the two are essential parts of the same mechanism.

I am deeply convinced that public participation is essential. I put this in first because I intend to talk mainly about the difficulties of public participation. I think it is sensible to do that because public participation is so important, but the mechanism just has to be improved. That is why I dwell on the difficulties, not because I think public participation is unimportant.

The first thing to realize is that we are talking about public participation on a complex land use problem because a transmission line is really one of the most important linear land uses. Pipe lines are another important one, and highways, and probably before long other rapid transit systems. In public participation on a complex land use

problem the first requirement is good two way communication. We must not think of the public hearing process as one way communication. The person or group who are seeking to build a new linear land use must try to communicate to the public both the importance of their objective and the details of their methods, plans and problems. The public must then react to this information and say what they think about it. Don't think of the public participation process as just listening to people gripe. It is a two way process. The proposal being advanced must be understood by the public and the public views must be understood by the hearing body. In the process there is a great deal of room for what the French call social animation because as I will outline, one of the real problems is getting everyone interested in participating in a public debate about the proposal. At this early stage of education the discussion must be a circular one because each side should modify its views in response to the attitude of the other.

An important thing to realize is that in these processes no one is on trial. The aim of the whole process is to find what I think is often rightly called the "least worst" solution to a very difficult problem.

The elements which are essential to a successful public participation or series of public hearings are first, a carefully prepared simple and readily understandable study, not just of the route being presented but of the entire area affected and of the environmental, social and economic impact of a variety of alternative routes. Ontario Hydro discovered in their recent experience that the critical problem here is to try to make the presentation simple and understandable to the ordinary person. This is often quite difficult for the expert engineer. One of the great pleasures of my three years experience was to see the improvement that hydro made in their presentation. This was partly coming to understand the needs of the situation and partly due to selecting their spokesmen. Some people have a natural gift for simple communication and others don't. Quite often the best expert is not particularly good at communication of a complex problem

to the public. As you probably heard, Ontario Hydro developed a sort of catch phrase that "Mum's the word" for these presentations. In other words, if you make the presentation so that it is quite intelligible to your ancient grandmother then it will probably get across to the public.

It is important in these hearings that there should be an advocate to support and define the selection of one of the alternatives presented. This doesn't sound important but its absence can greatly inhibit the tasks of eliciting information. This was one of the weaknesses of our hearing. In the first hearings, Nanticoke to Pickering, Ontario Hydro presented a recommended route initially. I didn't accept it because they hadn't done an adequate study of the area but had picked out a route that was not bad. So we got a consultant to do a complete study of the area. This was done starting with the public and bringing the public along and when the hearings came along the consultant was there to defend his choice. In the second case Ontario Hydro had a consultant, but the consultants took very little part in the later hearings and Ontario Hydro's view tended to be "all we want is a route acceptable to the public so that we can build the line quickly." This attitude doesn't make for a good debate. It doesn't bring out the pros and cons of different groups and so it is important that somebody be present at all the hearings to support and defend a particular route. Otherwise the discussion just becomes a series of statements of opposition to every route.

Probably the most important and difficult part to the whole process is trying to round up and maintain a representative audience. This involves first of all what sounds at the beginning to be the very simple question of getting in touch with the public. I could spend the whole morning telling you horror stories of how we tried to get in touch with the public and failed. To cut a long story short, at the very last hearing of the commission on the

Lennox to Oshawa route, when this problem had been actively discussed by the public in a series of nearly one hundred meetings over four years, a man appeared to say that he had just built a house on one of the proposed routes and hadn't heard until that morning of the possibility of there being a power line build anywhere in the area at all. Don't get the idea that it is easy to get in touch with the public because it is not. We tried every sort of thing and even in one case Ontario Hydro tried mass mailing to everyone on the local tax list. They found that the tax lists were not up-to-date and that many of the people who owned the property didn't live in the area and so on. No matter what you try, people will continue to turn up at the hearings right to the very end to say that they have never heard about and they will of course be irritated about it.

At the hearings, assuming that you have got in touch with the public, the audience usually consists mainly of those who are apprehensive lest their own property be adversely affected by the proposed line. Obviously this is not the ideal audience. The ideal audience would not only contain these people who had a special interest, but also representative citizens of the whole study area together with representatives of special interest groups such as environmentalists, agriculturists, those concerned with recreation and so on. I'll come back to the problem of how I think this might be done. However, the important problem is that the so-called "concerned citizens" who oppose one route will not come to meetings about another route, but a new group of concerned citizens opposed to the new route will appear. So there is a real danger particularly if the Commission moves from one area to another or deals with alternative routes at separate meetings, the hearings will become entirely negative with only those who are opposed to a particular proposal appearing.

In spite of the need to insure that there is always

someone supporting a project against those who attack, it is absolutely essential in these public hearings to avoid the adversary atmosphere of the courtroom. In our hearings most of the people who appeared were farmers and farmers are generally shy people and are often inexperienced in public appearances. Quite often a farmer may have something important to say, but he won't say it if the atmosphere is unfriendly. On the one or two occasions when someone took a legalistic attitude to evidence and was really aggressive with a witness, the discussion just stopped. The right atmosphere can be created but it does mean restraining some of the more enthusiastic members of the legal profession who are used to the adversary process and who usually set out to prove something and assume that everybody else is setting out to prove the opposite. This attitude should be kept out of the hearings. The atmosphere should be one of simple enquiry in which everyone is trying to get at the truth of the matter.

One of the most important problems of the public hearing in the case of the Solandt Commission was to try to ensure that the hearings did not short circuit the mechanism of government. I feel that this is a very important warning to make now because we are tending to forget in our enthusiasm for public participation that when the public come and talk to a commission and then the commission makes recommendations directly, through a cabinet minister to the Provincial Cabinet, the entire mechanism of municipal government is being short circuited. The municipal government is responsible for dealing with local problems and should be the spokesman for local people. In planning for a long linear land use it is obvious that several municipalities will be involved so it is very easy to say that the best way to deal with it is to ignore the municipal governments, deal directly with the people and take their views and recommendations to the provincial

government. The Ontario Government has said that they hope, in the future, to pass responsibility for land use planning, within Provincial guidelines, completely to municipal governments. The municipal governments must then take full responsibility for mobilizing and listening to local public opinion and for taking active part in any hearings that are held. In my experience a good many of the municipal governments were delighted to be short circuited because as you can imagine the location of a power line across a municipality is the sort of thing in which the local politician just can't win. His only alternative is to oppose all possible routes because if he opposes one route and not another he loses votes so the easiest way is to have a commission come in over his head. He can sit on the fence and watch as many of them did. In saying this I don't want to imply that all the municipal elected representatives did this; some of them did their best to grapple with the problems and to contribute toward a sensible solution.

One way of getting around this difficulty, and I think it would also be a useful way of insuring a continuing audience for the hearings, would be to have each municipality potentially affected by a powerline, nominate a panel of citizens to attend hearings to act as a two way link between the hearing body and the municipality. This, of course, raises problems of time and pay and it may be that it would be necessary to have several different representatives covering separate parts of the hearings, but I am convinced from my experience that it is going to be necessary to have designated representatives in order to get some degree of continuity. The worst effect of lack of continuity is that the audience does not become cumulatively educated as the problems are presented sequentially to the commission and this inevitably leads to boring repetition. I don't think we had a hearing in three years in which somebody didn't get up and ask why all the lines couldn't be put underground. We spent several days listen-

ing to experts from Canada, Britain, and the United States, outline the problems of underground transmission. They were unanimous in concluding that a 500 KV line shouldn't be put underground in a rural area at this time, but in every hearing this problem came up again. The usual statement was something like, "My wife's uncle is an engineer and he says the lines can be put underground and I won't believe it if you tell me they can't." It is very difficult for the Commissioner to keep reiterating and summarizing such information because this inevitably puts him in the position where he appears to be supporting one or another view. Unfortunately in many cases the experts had come and gone and there was no one left but the Commissioner to give a summary of earlier testimony. I would suggest that where expert testimony on a particularly important subject is heard it should be quickly edited into a brief pamphlet for public consumption so that when somebody comes and says, "I think the lines should be put underground." he can be given a copy of the appropriate pamphlet and be asked to read and digest it before asking further questions.

Think of the problems that the Porter Commission, that has just been established to look at the Ontario Hydro long range plan for 1983-93, will have if they have to repeat the same hearings on a tremendous range of technical problems at every major point in Ontario. They will obviously never finish and the whole province will end up in the dark. So they will have to find an answer to this problem of repetition.

Let me conclude by saying that the real problem that we are facing here is the need to change our basic attitude to the rights of the property owner. We can no longer permit him to do what he likes on and with his own property. Not only must he avoid pollution and other nuisances which affect his neighbours adjacent or further afield, but he must also begin to accept the necessity for a variety of encroachments by the community in the interest of the community.

The task that must be faced in future public participation is to convince the landowner that the encroachment being proposed is necessary, that it has been well thought out, that all alternatives have been examined, that the total benefit is great and that he will not be asked to pay more than his fair share of the total economic and social price. This obviously is going to require new laws. The laws must define and control this relationship, but far more important than new laws is a change in attitude towards land ownership. The feeling must become widespread that the welfare of the community must, in many cases, take priority over the old fashioned property rights of the individual. In the meantime we have to get on with a great many construction and development programmes. You are the people who are going to work with the public in getting acceptance for these new projects as they arise. The basic elements in a good programme of public participation are first good education of the public in the background of the problem. Here I think it would be quite sensible to separate this educational process from the actual hearing and also to the educational programme done by some authority quite different than the one who is presenting the case. For example, when Ontario Hydro is seeking a right-of-way for a power line, it is difficult for it to convince the public that when Hydro described the characteristics and problems of power lines in general that this is an objective and unbiased statement of the problems. The public will always suspect that they are being given a special view of the problems of transmission lines in order to justify a particular route. There is a great deal to be said for separating the educational process from the actual discussion of specific proposals.

Overriding all of these needs is the need for continuity in working towards changing our attitude towards land ownership. We must come to see that all should be available for community purposes when the needs of the community are seen to override those of the individual. You

are starting into a very interesting period in which Ontario particularly, is just undergoing this transition in land use planning and control and the attitudes towards land ownership. You have an important job to do in helping to steer this transition wisely. I am sure you will do it well and that you will enjoy doing it.

CONSTRUCTIVE CITIZEN PARTICIPATION

A Positive Factor in Environmental Planning

The experience of citizen participation in locating waste disposal facilities to date has been typically a negative backlash following the announcement of a decision. Environmental planners wince at the roll call ... Port Hope, North Pickering, Oakville, etc. Constructive citizen participation is a use-tested model of positive public involvement, an integral part of the planning process. It commences at the start of a study and parallels its phases to its conclusion. The participative planning process employed consists of five phases ... start-up, data collection, development of alternatives, evaluation and decision.

The relationship between this process and environmental legislation is outlined, together with the implications for industrial firms and consulting engineering companies.

by

DR. DESMOND M. CONNOR

Consulting Sociologist and President
D. M. Connor Development Services Limited
Oakville, Ontario



Dr. Connor is a consulting sociologist (Ph.D., Cornell University) who has specialized in the design and management of citizen participation programs for the past five years. These included highway relocation studies, regional planning in Ontario, river basin planning in eastern and western Canada, transmission line corridors in Ontario and B.C., a new town near Toronto and a federal highway training program in the U.S. He has worked for several years in management training and organizational development including membership in multi-disciplinary teams. He also leads a graduate seminar in participative planning in the School of Urban and Regional Planning at the University of Waterloo.

CONSTRUCTIVE CITIZEN PARTICIPATION
A Positive Factor in Environmental Planning

by

Dr. Desmond M. Connor
Consulting Sociologist and President
Connor Development Services Ltd., Oakville, Ontario

INTRODUCTION

The experience of citizen participation in locating waste disposal facilities to date has been typically a negative backlash following the announcement of a decision. Those involved in this field wince at the roll call - Port Hope, Vaughan, Pickering, Halton etc.

The purpose of this paper is to outline a use-tested process which has been used for locating controversial facilities such as highways in a variety of settings across Ontario and also in other projects in eastern and western Canada. The application of this process to environmental planning will be illustrated by presenting the design of a public participation program for use in a solid waste management study.

WHAT IS CITIZEN PARTICIPATION?

Constructive citizen participation in planning a project is a systematic process which provides an opportunity for citizens, planners, elected representatives and members of relevant area agencies to share their experience, knowledge and goals, and to combine their energy to create a plan. This plan can then reflect their knowledge and best judgment at the time and will be understood and actively supported by most of those affected by it.

I believe the public always participates in major decisions which people feel are important to them--but too often this participation is too little,

too late and too negative to be useful. Politicians and planners can therefore hardly choose whether or not to have public participation, but they can help it to take on a positive character.

Constructive citizen participation is happening when:

- * planners listen to residents concerning their attitudes, goals, fears and factual suggestions;
- * citizens find early and convenient opportunities to make positive contributions. ("Citizens" may include visitors as well as residents e.g. when tourists and cottagers are part of the public.)
- * citizens learn from planners and others a broader and deeper knowledge and understanding of their environment, its potential and its fragility;
- * individuals, interest groups and agencies are identifying their own positions, recognizing those of others and working towards a win-win solution co-operatively rather than becoming locked into a destructive win-lose or lose-lose pattern;
- * relationships between planners, politicians and other people are strengthened so that communication barriers are breached, and mutual trust increases as a foundation for communities to function more effectively in every way.

Constructive citizen participation is NOT:

- * selling a pre-determined solution by public relations techniques;
- * planning behind closed doors when information can be shared;

- * one-way communication, e.g. planners telling people what is best for them;
- * public confrontations between "people power" versus the bureaucracy;
- * bypassing elected representatives or impairing their freedom to exercise their decision-making responsibilities.

BENEFITS

Among the benefits to be obtained through constructive citizen participation are the following:

Data on goals, attitudes, values, preferences and priorities are a crucial input to the planning process. Their only valid sources are the citizens affected. Attempts to give people what planners think is best for them or what planners think they want, have led to one debacle after another. Such disasters leave behind the original problem, a heavy financial expenditure with little to show for it and a corrosive residue of ill-will.

Creative capacity for perceiving solutions to problems is not a prerogative of technical experts. Indeed, their training often equips them with as many blinkers as insights. Concerned laymen can often see sound alternatives which experts do not. e.g. A technically sound alternative route for Highway No. 417 in Ottawa was identified by a Citizens' Group; many teams of specialists had considered the problem for years without reporting this technically sound and widely acceptable solution.

Additional data, important to planners, can be provided by persons who often have decades of year-round experience of the environment. When official records are often recent and the project does not permit a full year of original data collection, the systematic recruitment of local observations can supplement other data sources.

Technical expertise in the key subjects of the project is often possessed by residents of the area. They can contribute this valuable resource in support of the project or if alienated, can conspire powerfully against it. Constructively involving these people is a survival skill essential for project success!

Involvement in planning is demanded by increasing numbers of citizens who want to experience the process of creation as well as its product. Often they have a substantial sense of ownership in their part of the environment--to ignore this is insulting.

Managerial solutions for environmental problems (as opposed to purely structural solutions), require changes in people's behaviour. The likelihood and ease of citizens changing their behaviour is greatly increased if they systematically become aware, interested, informed and thus convinced that new behaviour is needed. Placing new recommendations into traditional mentalities increases the need for regulatory legislation, enforcement procedures and a needless proliferation of a law and order society. Who needs it?

For example, it is clear that our capacity to generate waste far exceeds our capacity to dispose of it in ways that are environmentally sound, inexpensive and politically acceptable. During the citizen participation component of a waste management study, the public in the study area become increasingly aware of what they can do to reduce the volume of waste and facilitate the disposal of what remains. An integrated approach by community organizations, consumer groups and environmentalists in a given area has a powerful and untapped potential to reduce overpackaging, increase separation and foster the acceptance of better disposal methods.

A USE-TESTED MODEL

This approach to constructive citizen participation has been developed and applied to river basin planning in eastern and western Canada, highway location studies across Ontario, regional official plan preparation and hydro transmission line corridors. Its stages are designed to parallel the steps in the usual planning process which is outlined below for a 12-month study.

1. Start-up (1 month)

The objectives of this stage are to gain a rapid appreciation of the character of the community and the issues it faces, contact key citizen leaders, detail the design of the participation program, recruit, select and orient staff and prepare and distribute an introductory brochure on the project.

2. Collecting Information (3 months)

The focus now is on identifying the different publics and gaining a comprehensive understanding of each--the values, goals, attitudes and knowledge of the people, leadership patterns, relevant organizations, communication channels, reactions to the project, criteria seen as important in making project decisions, etc.

Growing mutual understanding should enable the various interested parties to start working together. A foundation of acceptance and increasing trust should develop, fostering a co-operative climate for the definition of shared goals and a common effort to achieve them. If this does not occur between the agency and the main citizen organizations, a coalition amongst various citizen groups and others interested is likely to occur, predicting well organized confrontations in the future.

3. Mutual Education (6 months)

The objective of this phase is to ensure that each party has a full appreciation of the viewpoints of each other party so that blind spots are eliminated and shared goals become evident as a focus for action.

In a waste management study, for example, this phase would commence with the distribution of information concerning waste generation, population, land use, environmental conditions and currently proposed solutions and locations. Individuals and groups would be asked to review this material, raise questions about it, contribute further ideas for solving the issues at stake, etc. This would involve a variety of meetings between those concerned.

4. Public Preferences (1 month)

By this time, with the help of citizen contributions, a number of technically sound methods and locations have been developed and evaluated in terms of the criteria put forward by citizens and planners. The objective now is to discover how socially accepted and politically viable each solution is by seeking the preferences of the public as fully as possible. Individual and group responses are tabulated by areas, and combined with technical information in a final report.

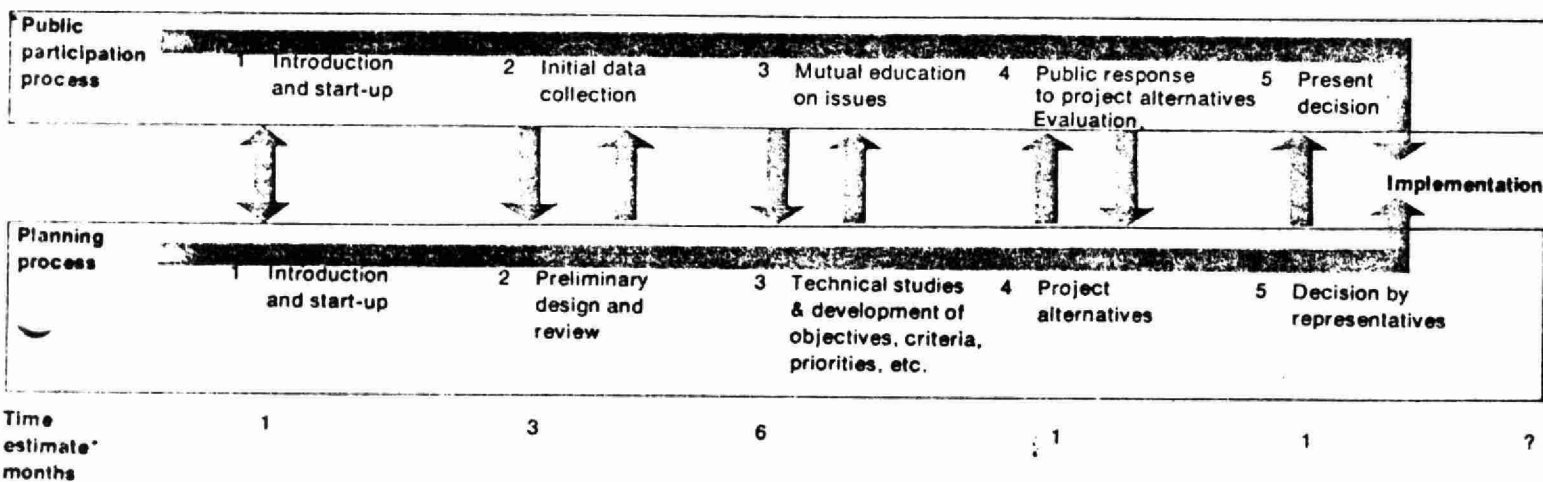
5. Decision and Follow-Up (1 month)

Once the decision on the project is made by the elected representatives, the agency responsible will communicate it, and the reasons underlying it, to all involved. Particular concern will be given to those adversely affected by the decision. It is important that those who contributed to a study be kept informed of steps toward implementation or unnecessary complications may occur. An evaluation of the participation program is essential if future activities are to be carried out more effectively.

Staff

To carry out this program effectively requires a high level of staff competence and a level of other resources which will ensure that most citizens have a realistic opportunity to learn about the issues and express their preferences on them. To do less is to invite needless trouble.

Public participation in the planning process



*Based on a one year planning process

The staff skills required are demonstrated by a proven capacity to carry out community research, group work and adult education. A master's degree in one of the social or behavioural sciences, followed by at least three years' successful field experience, is usually the background of the successful citizen participation representative. The capacity to focus on inter-personal and intergroup processes is critical to the success of these persons.

More specifically, staff are selected, trained and managed in terms of four roles which are successively accumulated during the project. These are the facilitator, social researcher, community educator and publicist.

An interpretive writer is required on a part-time basis to prepare material for public use and to co-ordinate information for the media. Statistical clerks will be obtained as needed to tabulate the responses indicating public preference.

Budgets

Budget estimates vary widely with the technical nature of the project, the community or regional setting and the design criteria selected for the participation program. Staff time usually accounts for half the participation budget. Once a detailed program of work is developed and media costs are estimated, an approximate budget can be established.

While there are no easy rules of thumb, the participation budgets on recent projects have varied from 20 to 60% of the technical planning budget, depending largely on the size of the population in the study area.

AN ILLUSTRATION

The following design was prepared and submitted over a year ago for a solid waste management study requested for a regional municipality in Ontario. The region is characterized by a strong industrial base, fertile farm land, a university with environmental interests and a population of some 300,000. The program of work was tightly scheduled due to external pressures.

Goals and Objectives*

This proposal has been prepared to accomplish the following broad goals:

1. To educate the public in the principal issues concerning solid waste disposal so that completely unrealistic sites and methods will not receive wide public support. Rather, public preferences concerning technically sound sites and methods will be identified as an aid to municipal and provincial decision-making.
2. To minimize the prospects of a technically sound report being shelved during a period when economical investments in sites or technology could have been made.
3. To co-ordinate activities connected with this program with those of the Regional Official Plan process so that mutual reinforcement occurs rather than collective confusion.
4. To provide a working model of how constructive citizen participation can

* This section is a slightly edited version of an actual proposal.

contribute to identifying solid waste management decisions which are both technically sound and politically viable.

5. To enable interested regional and M.O.E. staff and selected students to observe this program unobtrusively, learn from it and be more able to contribute to improved programs in the future.

More specific objectives to attain the above goals include:

1. Initial orientation of elected representatives; later, providing them with previews of major subsequent phases.
2. Understanding of the people of the region--implications of life values and goals, organizational networks, media use, leadership, etc. re solid waste management.
3. Assessing and extending the knowledge people have of solid waste issues, including technical criteria for sites and processes.
4. Inviting the public to contribute (a) any additional sites which they feel the technical study group should assess, (b) their weights on evaluative criteria for sites and processes.
5. Presenting technically sound sites and processes, to the public of the region, soliciting their preferences amongst them, and analysing the results.
6. Presenting findings of public preferences to elected representatives, together with technical data.
7. Briefly evaluating the public participation program.

Program of Work

February 22	Start-up: orientation by regional officials; brief brochure prepared indicating relationship with Regional Official Plan.
March 1	Orientation for elected representatives. News conference. Identification of key human factors in regional population e.g. knowledge re waste management issues, relevant values and goals, leaders, organizations, media etc.
March 15	Preparation of tabloid, based on interim technical report and above findings; mail back questionnaire re criteria, weights and added sites.
April 15	Tabloid distributed; public exhibit for two days in three shopping malls soliciting suggestions, weights, etc.; contributions to radio hotlines, T.V. public affairs programs, etc.; meetings with organizations as invited.
May 1	Analysis of response by areas; transmission to technical group and feedback to public. Further meetings with groups as requested.
May 8	Technical group review any proposed additional sites.
May 22	Technical group complete analysis of any additional sites.
June 5	Full page advertisement soliciting public preferences on

technically sound sites and processes; mail
back questionnaire from individuals, and from
interested groups; public exhibition for 2 days in
3 malls; response to media by resource persons.

June 16 Response deadline; analysis by areas.

June 24 Report of results. Evaluation of program and short
report.

July 12 End of project.

Note -- This program would be subject to adjustments required
to obtain harmony with the Regional Official Plan
process. These are unlikely to materially shorten the
above work schedule.

Staff Requirements

Given the characteristics of the study area situation and this program of
work, staff needs are as follows:

- * One experienced Participation Worker capable of working with both
urban and rural people. A background in applied social science,
personal maturity and a vehicle are essential. This is a full-time
position; during peak periods, this person will require supplementary
assistance e.g. to staff public exhibit and simultaneously to handle
media and group requests for information; analysis of data.
- * The part-time services of an interpretive writer to assist in trans-
forming technical material into Tabloid form; some graphics assistance.

- * The specialized services of a senior consultant to plan, design and manage the program, and take responsibility for it.
- * The specialized services of engineers familiar with the details of the Solid Waste Management Study for the Regional Municipality.

Budget Estimate

1. Participation Staff		
(200 hours/month for 5 months at \$14/hr.)		\$14,000.
2. Management and Technical Supervision		\$ 7,500.
3. Engineering staff:		
General (12 days/month for 5 months		
at \$200/day)	\$12,000.	
Public Exhibits (18 days at \$200/day)	\$ 3,600.	
Meetings (3 persons for 5 hours/		
meeting at \$450/meeting for 20		
meetings)	<u>\$ 9,000.</u>	
		\$24,000.
4. Interpretive writer and graphics		
assistance		\$ 1,000.
5. Printing - Introductory Brochure	\$ 500.	
- Tabloid	\$ 6,000.	
- Full Page Advertisement	<u>\$ 1,000.</u>	
		\$ 7,500.
6. Spot advertising of meetings, tabloid response		
deadlines, etc.		\$ 1,000.
7. Travel and Meeting Expenses		<u>\$ 3,000.</u>
	Estimated Total:	\$58,600.00

This estimate is based upon average to good conditions and a 5-month project; it is not an upset limit.

It is assumed that the Ministry of the Environment would supply some general informative literature and public display graphics concerning solid waste management as they suggested.

None of these items can be dispensed with or significantly reduced if the program is to remain viable.*

NEW APPROACHES TO ENVIRONMENTAL PLANNING

The proposed Environmental Assessment Act, before the Ontario Legislature at the time of writing, is the first step in radically changing the approvals process for major projects. While it will apply initially only to government projects, it is intended to apply eventually to all major industrial and commercial development. Whether or not the amendments proposed by various groups to strengthen the initial Bill are accepted at this time, we are clearly moving into a period when all substantial public and corporate projects will be assessed not only by technical and economic criteria, but with reference to environmental guidelines and public acceptance as well. The purely engineering study will give way to a multi-disciplinary investigation by a team of engineers, ecologists and social scientists, as has become the pattern in highway feasibility studies.

These studies will be more difficult to manage, will take longer to complete and will be more costly than those of the past. But they will be "cost

* Note: This proposal was rejected on the basis of cost factors and political sensitivity.

effective through cost avoidance" as a Government Committee on Productivity report stated several years ago.

The challenge to those involved in the field of industrial waste management--administrators, engineers, planners and scientists--is how to integrate their contributions so that the results of their work are satisfactory to all involved--themselves, their superiors and the ultimate client--the citizen-taxpayer.

No one said this was easy--but it is possible if we make the commitment to do so. Do we really have any choice?

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ENVIRONMENTAL ASSESSMENT - THE EXPERIENCES OF
THE MINISTRY OF TRANSPORTATION AND COMMUNICATIONS

Federal and State Legislation related to this subject has been in effect in the U.S. since 1969 & 1970. In Canada the Federal Government has declared by Policy, that Environmental Assessments are mandatory on all Federal projects. The Province of Ontario is currently preparing legislation to initially cover Provincial projects and eventually to cover all projects including those by the private sector. Since 1971, the Ontario Ministry has been actively developing an organization, staff, technical methods and procedures with the goal of integrating environmental factors and public participation into all of its decisions and programs from planning through to construction and maintenance. Drawing on the experience of the last four years, this paper outlines the methods developed to date for meeting not only transportation goals but also environmental goals as viewed by many agencies and sectors of the public. Basic and traditional stages are used to discuss environmental factors and impact.

by

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ENVIRONMENTAL ASSESSMENT - THE M. T. C. EXPERIENCE

I. V. Oliver, Head, Environmental Office

Ontario Ministry of Transportation and Communications

INTRODUCTION

The purpose of this talk is to try to highlight the Ontario Ministry of Transportation's (M.T.C.) experiences in environmental studies over the past four years, how these experiences stand us in the face of impending environmental assessment legislation in Ontario; and, hopefully some lessons that could be of help to those of you in the municipal and private sectors in responding to the legislation.

THE EVOLUTION OF MANDATORY ENVIRONMENTAL ASSESSMENT

By way of a brief historical note, the term Environmental Impact Statement (E.I.S.) in the mandatory sense, began to make its way into the vocabulary of transportation agencies in the United States in 1969. Its interjection into transportation, and other development, decisions and implementation was initiated by the provisions of the U.S. National Environmental Policy Act of 1969. The preparation and submission of Environmental Impact Statements became mandatory on Federally funded projects having significant impacts on the environment.

Since then the objectives of this legislation have been adopted in one way or another by many States in the U.S. and by other countries such as the U.K., Australia and Canada. The degree to which an E.I.S. is a mandatory requirement varies from the essentially rigid requirements of the U.S. legislation to the fairly discretionary policy of the Canadian Federal Government.

After three years of operation the following observations were made in "NEPA In The Courts" (Anderson, 1973).

"Few cases exist where NEPA has materially altered a federal program or project in the three years following enactment of the legislation. There is also little evidence that this legislation has begun to implement the fundamental change originally intended by Congress. What has been accomplished, after many court cases, is a degree of compliance with the overall objectives of NEPA; and, at least an increased awareness of the role of environmental factors in decision-making has been partly accomplished. However, the record shows that in the majority of court cases the issues were related to the procedural compliance of NEPA rather than to a right or wrong decision on environmental protection per se.

The central inadequacies on the quality of E.I.S.'s appear to be:

- 1) failure to define impacts, to provide measurement tools, and to increase local participation in planning
- 2) the intended integration of engineering and environmental factors into the planning and design process has not materialized."

In the Fall of 1973 the Ontario Government, through a "Green Paper on Environmental Assessment" published by the Ontario Ministry of the Environment, made the initial step towards enacting legislation requiring an environmental assessment, of those projects having potentially significant impacts on the environment. The legislation arising from the public discussion of the alternative environmental assessment systems put forth in the "Green Paper" is expected this Spring.

To quote from the "Green Paper" the objectives of such legislation will be:

- 1) "To identify and evaluate all potentially significant environmental effects of proposed undertakings at a stage when alternative solutions, including remedial actions and the alternative of not proceeding are available to decision-makers.
- 2) To ensure that the proponent of an undertaking and governments and agencies required to approve the undertaking give due consideration to avoiding or mitigating any adverse environmental effects prior to granting any approval to proceed with an undertaking".

Only time will tell whether these objectives can be met without a serious slowdown in the development of many public and private projects which are truly needed by society; as has occurred in the U.S. There is as much onus on those required to comply with environmental assessment requirements, to ensure that such consequences are minimized, as there is on agencies responsible for the administration of such requirements.

THE M.T.C. APPROACH TO ENVIRONMENTAL STUDIES

In late 1970 a commitment was made within the M.T.C. to undertake a voluntary approach to studying and considering the environmental implications of all major projects at the route planning (location) stage. The necessary organizational and staff capabilities were not achieved, however, until June, 1971 with formation of what is now known as the Environmental Office.

At that time the former Department of Highways underwent a major reorganization to cope with the many new aspects of its responsibilities among which were environmental considerations, public transit, air services, conventional rail operations and marine facilities. Out of this emerged the

Ministry of Transportation and Communications with, among other features, Environmental and Project Planning Offices located within the Planning Division.

It is important to note here that this reorganization came about largely in response to public expressions that not only must decision-makers at all levels consider the environmental effects of conventional highway projects but also that future transportation plans and decisions must be based upon a broad and explicit consideration of all modes of transportation.

During the formulation of these new directions and the organization to go with them we looked very closely at the then recent experiences of various U.S. transportation agencies particularly with regard to their approaches to consideration of environmental factors and public participation in project development. As has been mentioned previously NEPA had made the preparation and submission of Environmental Impact Statements mandatory on projects supported by Federal funds.

The approaches which have been evolved since late 1970 in this Ministry stress total integration of environmental factors, engineering and cost factors with public involvement. In short we see the simultaneous consideration of all these aspects as essential to our internal decisions and project development process.

Our approach will be further expanded upon by explaining the meaning and application of what have been referred to as: "THE TEN PRINCIPLES" for living with environmental assessment. Following this we will explain a "CASE STUDY" for a highway location problem which will assist in suggesting some "BASIC GUIDELINES FOR ENVIRONMENTAL ASSESSMENT" with reference to an industrial plant location problem as an example.

We will offer some observations on "THE M.T.C. AND ENVIRONMENTAL

ASSESSMENT LEGISLATION", which will relate our experience to date to what we see ahead, followed by "CONCLUSIONS".

What we have learned to date and what will be tried and modified now and in the near future by the M.T.C. is discussed in the following with reference to each of the TEN PRINCIPLES.

PRINCIPLE I

DEVELOP AND ADOPT BASIC OBJECTIVES

Since 1971 the policy of the M.T.C. has been:

"to integrate the full consideration of relevant environmental factors, and public participation into our planning, design and decision-making process".

The operational objectives behind this policy can be simply stated as:

(i) to ensure the timely implementation of transportation programs and projects, and,

(ii) to ensure the minimization of negative environmental impacts.

PRINCIPLE II

DEFINE RELEVANCY OF ENVIRONMENTAL FACTORS

As with most builders and operators of physical plant we in the M.T.C. view the development and implementation of a transportation project in particular, as a continuous process from earliest planning to actual operation.

Figure 1 illustrates this process and the relevancy of environmental inputs to each decision or step in project development. We recognize of course that the process is not ideally free of recycling when subjected to the real world of varying time scales and changing and unpredictable conditions.

PRINCIPLE III

DEFINE SPECIFIC ENVIRONMENTAL OBJECTIVES AND SCOPE FOR EACH STAGE OF PROJECT DEVELOPMENT

The approach outlined in Figure I provides a basis for specifying the

FIGURE I ENVIRONMENTAL INPUT

SYSTEMS PLANNING

- . configuration and modal mix of long range area wide network;
- . level of service and timing of various links;
- . options to be protected in short range decisions

Regional environmental goals, objectives, restraints and opportunities influence system configuration, mix of modes and implementation timing.

ROUTE LOCATION

- . confirm feasibility of a route for each critical link in the system;
- . select "most likely" future route for right-of-way protection, etc.;
- . select a route for design studies from a broad range of alternatives

Corridor level natural and man-made environmental features provide basis for generation of alternative routes and evaluation of same.

PRELIMINARY DESIGN

- . determine basic horizontal and vertical alignment, cross-sections, interchange locations and configurations and major structure requirements

Solutions to specific environmental problems are dependent upon these aspects of design.

DETAIL DESIGN

- . finalize details of design and construction to be incorporated into contract documents

Solutions to environmental problems are justified on a cost-effective basis and defined in specific terms for bidding and contract supervision.

CONSTRUCTION & MAINTENANCE

- . ensure construction of project according to contract specifications
- . ensure maintenance according to pre-determined standards

Unforeseen environmental problems will require on the spot solutions. General environmental good house-keeping should be monitored. Environmental decisions on future projects can be improved through monitoring of solutions already in operation.

basic objective and scope of the environmental study component at each stage of project development.

Figures II and IIA outline our approach to achieving Principle III through:

- . relating environmental objectives to a decreasing degree of flexibility in project development
- . realistic and attainable environmental objectives at each development stage
- . scope of environmental study consistent with objectives of each development stage
- . full integration of environmental component with engineering and cost aspects of project study.

PRINCIPLE IV FULL PUBLIC INVOLVEMENT AND ENVIRONMENTAL ASSESSMENT COMPLEMENT EACH OTHER

Our original commitment to full public participation which was made in 1971 has proven to be one of the most significant steps taken by the M. T. C. in making our project planning and decision process more responsive to the environmental and social values of the 1970's.

Figure III outlines our approach to involving the public throughout say a route location or design study for a particular transportation project. To achieve the necessary dialogue between the public and the project planners we may rely on any one or a combination of:

- . large public meetings

FIGURE II A

OBJECTIVES

SCOPE

SYSTEMS PLANNING

- to identify environmental constraints and opportunities as a basis for development and evaluation of alternative transportation systems
- to ensure that any environmental constraints will not jeopardize the feasibility of critical links in the adopted system

- Inventory and analysis of:
 - regional development goals and objectives
 - established and future community and neighbourhood boundaries
 - unique landforms and major visual features
 - significant biologically sensitive areas e.g. lakes, rivers, wetlands, woodlots
 - major resource areas e.g. mining, tourism, forestry, agriculture

ROUTE LOCATION

- to identify natural and man-made features as a basis for the generation and evaluation of alternative routes from the viewpoint of minimizing negative environmental effects
- to indicate for the adopted route the environmental restraints to be adhered to and problems to be resolved in subsequent planning and design activities and decisions.

- Inventory and analysis of:
 - local development goals and objectives
 - community and neighbourhood services, characteristics and development patterns
 - social and economic characteristics
 - local commercial and manufacturing activities and areas of influence
 - significant biologically sensitive sites
 - surface and subsurface waters sensitive to changes in quality and quantity

FIGURE II B

OBJECTIVES

SCOPE

DESIGN

- to identify natural and man-made environmental features with the view of minimizing the negative impacts of the anticipated alignment or maximizing positive impacts
- to indicate for the selected alignment the precautions or protective measures that apply that will minimize the environmental impacts at the construction and operational stages

- Inventory and analysis of:
 - locations of buildings, in proximity to the facility, business, service movements etc. that might be affected by the improvement of the facility and/or its change in designation
 - the visual amenities of the selected alignment and opportunities for improvement
 - sensitivity of the water drainage - soil interface associated with proposed drainage schemes
 - restraints and conflicts to be resolved as identified in previous studies

CONSTRUCTION

- to implement environmental design features and construction methods which will ensure appropriate level of environmental protection and quality control

- Inventory and analysis of:
 - construction activities and circumstances which may cause either a beneficial or detrimental environmental impact
 - problems to construction activities acting as constraints to environmental protective measures
 - solutions to environmental problems encountered under similar circumstances on other projects
 - cost effectiveness of proposal measures

STUDY STAGES

	<u>Purposes</u>		<u>Interaction</u>
I	<u>Input</u>		
	. introduction to study . collection of additional information, values, concerns etc.	PARTICIPATION CYCLE MEETING I	. local information, such as historical buildings, biological areas, community structure etc. presented by the public . local concerns e.g. loss of farmland, severances, noise etc. presented . planners present general information of the area, need for a new facility and introduction to the study . all concerns and information documented for future use
40 I	II	<u>Development of Alternatives</u>	
	. identification of solutions to problems with a view of minimizing the impacts as much as possible.	PARTICIPATION CYCLE MEETING I or II	. public provides their ideas to problem solution . planners present their ideas on problem solution
	III	<u>Evaluation of Alternatives</u>	
	. to narrow the range of potential solutions to the problem to those with a minimal impact.	PARTICIPATION CYCLE MEETING II or III	. public rates the alternatives . planners rate the alternatives . number of alternatives is narrowed
	IV	<u>Decide on the Solution</u>	
	. to select that alternative which will best satisfy all factors.	PARTICIPATION CYCLE MEETING III or IV	. approving authority (Minister) makes selection based on planner's recommendation and study information provided . decision is passed to the public via brochures, newspapers etc. . additional meetings with dissenting public groups may be necessary.

- . small neighbourhood meetings
- . citizens advisory groups
- . drop-in centres
- . interviews and questionnaires.

It should be noted that the most effective means of having the public review a project proposal is through their direct involvement in the development and evaluation of alternatives.

We believe that such participation will obviate much of the reactive type of public involvement provided for in a formal hearing.

PRINCIPLE V DEVELOP SUBSTANTIATED CRITERIA FOR
SCREENING OUT PROJECTS NOT REQUIRING
A FORMAL ENVIRONMENTAL ASSESSMENT
OR STUDY

Within the M.T.C.'s five year program there are many proposed transportation improvements which, as a category of projects, do not easily lend themselves to an a priori designation as requiring a formal environmental assessment. Figure IV gives an example of the environmental screening criteria used by the M. T. C. for the last year as an internal management tool as well as in anticipation of formal environmental assessment legislation.

The screening of a proposed project which indicates a number of medium or high potential impacts would result in at least a fairly in depth environmental study if not formal environmental assessment.

FIGURE IV ENVIRONMENTAL SCREENING SYSTEM

Screening Criteria (Example)

<u>Factors</u>	<u>Impact</u>
Roadside Vegetation	High - Removal of more than 50% of existing mature trees in a rural area - removal of very large or unique trees - removal of more than 25% of existing mature trees in an urban area Medium - Removal of 25% - 50% of existing mature trees in a rural area - removal of 10 - 25% of existing mature trees (urban area) Low - Removal of less than 25% of existing mature trees in a rural area - removal of less than 10% of existing mature trees in an urban area - structures - no trees removed

PRINCIPLE VI

ADAPT CURRENTLY PRODUCED PLANNING
AND DESIGN DOCUMENTS TO REFLECT AN
INTEGRATED ENVIRONMENTAL ASSESSMENT
BASED STUDY AND/OR DECISION

The preparation of project documents within the M.T.C. has stressed the integration of the environmental study component with engineering and cost considerations. This reflects a truly comprehensive environmental assessment of all impacts and trade-offs as well as stressing our interdisciplinary approach to each study that culminates in such a report.

Figure V provides a brief outline of the basic reports produced during the key phases of project development with an emphasis on the contents related to environmental factors. These normal M.T.C. documents will form the basis for formal environmental assessments as required for designated projects.

PRINCIPLE VII

INCORPORATE ENVIRONMENTAL CONSIDERATIONS
INTO ESTABLISHED PRE-CONTRACT REVIEWING
AND REPORTING PROCEDURES

Throughout the project development process there are a number of key decision points at which agency commitment to future action is made. Often, these key decision points are related to the selection of alternative action courses; although others may not be directly related to such a major decision. The major decision stages are crucial from the standpoint of obtaining agency commitments based on a proper balance between costs and environmental values.

Figure VI presents the major decision points in the Ministry of

FIGURE V

INTEGRATED ENVIRONMENTAL-ENGINEERING REPORTS
FOR ENVIRONMENTAL STUDIES

PROJECT STAGE

REPORT CONTENTS

SYSTEMS PLANNING REPORT

- documents environmental restraints to the recommended system
- identifies constraints and gives reasons for the rejection of alternative systems based on the anticipated impacts from such constraints
- gives details of Public Participation Program including concerns.

ROUTE-ALIGNMENT REPORT

- details positive and negative impacts of route / alignment selected
- provides details on the positive and negative impacts of alternatives considered and reasons for selection of the recommended route / alignment
- provides details on the concerns, values etc. of the Public Participation Program.

DESIGN REPORT

- provides information on how the residual environmental concerns are to be designed out
- provides details on the alternative designs considered and reasons for rejection including cost effectiveness analysis.

CONTRACT DOCUMENTS

- construction details specified in drawings, special provisions etc.

FIGURE VI

INCORPORATION OF ENVIRONMENTAL CONSIDERATIONS
INTO ESTABLISHED PRE-CONTRACT REVIEWING
AND REPORTING PROCEDURES

DECISION STAGE

FORMAL REVIEW

SYSTEMS PLANNING

- adequacy in terms of transportation service
- environmental constraints avoided
- environmental restraints recognized.

ADOPT ROUTE/ALIGNMENT
(Designation)

- adequacy in terms of transportation service
- minimized environmental impacts
- residual impacts identified for action at next stage.

ADOPT DESIGN

- design adequate for transportation service
(Design Criteria)
- adequacy and practicability of environmental
protective measures.

AWARD CONTRACT

- contract documents specify environmental
protection measures at a satisfactory level
consistent with the sensitivities observed
- contractor briefed as to the intent.

Transportation and Communications project development process and indicates the necessary review items which lead to a decision.

PRINCIPLE VIII ASSEMBLE A CORE STAFF OF QUALIFIED ENVIRONMENTAL PERSONNEL AND ESTABLISH WORKING RELATIONSHIPS WITH ENVIRONMENTAL AGENCIES, GROUPS AND CONSULTANTS IN BOTH THE PRIVATE AND ACADEMIC SECTORS

Originally the Environmental Section was set up in the Ministry's Planning Division so that through its on-line involvement in route selection, the most rapid integration of environmental factors in the Ministry's activities could be achieved at a stage where transportation decisions were still relatively flexible. Experience has borne out that the ideal organizational location for such a centralized group is in association with project planning. In this position the Environmental Staff can relate most effectively to projects both upstream in planning and downstream in design and construction.

The Ministry has chosen to create a central group of people with backgrounds in the various environmental disciplines because:

1. The state-of-the-art in defining and solving transportation related environmental problems was and is, relatively undeveloped.

A small group of properly motivated people tend to generate innovative approaches more effectively than individuals of one professional background spread thinly throughout an organization made up of people with a different background.

2. The priorities on environmental factors as indicated by groups and agencies outside of the Ministry of Transportation and Communications can be more objectively measured by a central environmental group and in turn be more realistically related to the Ministry's transportation objectives.
3. The Ministry can more effectively achieve consistency in its treatment of environmental factors from office to office through the development of policies, procedures and guidelines under the direction of a central group.

The Environmental Office provides its environmental expertise to other offices and divisions in the M.T.C. on a project specific basis or it co-ordinates the joint development of environmental guidelines and procedures with other offices.

PRINCIPLE IX USE AN INTERDISCIPLINARY TEAM APPROACH
AND BEST AVAILABLE ENVIRONMENTAL IMPACT
DETERMINATION METHODOLOGIES

Integration of transportation engineering/environmental studies has been achieved in our route location studies by using a multidisciplinary team approach. These studies are complex and comprehensive due to:

- . the multi-modal scope of the transportation planning aspects,
- . the broad range of factors which must be considered,
- . the great number of agencies, individuals and groups who may have an interest in, or be affected by, the results of such studies.

The necessary multidiscipline, multi-interest team is comprised of:

- . professional disciplines such as Engineers, Biologists, Geographers, Transportation and Urban Planners, Economists, Sociologists etc.
- . Government Agencies at all appropriate levels.
- . Elected Officials at all appropriate levels.
- . Citizens Groups.
- . Commercial Interests.
- . Other interested and affected individuals.

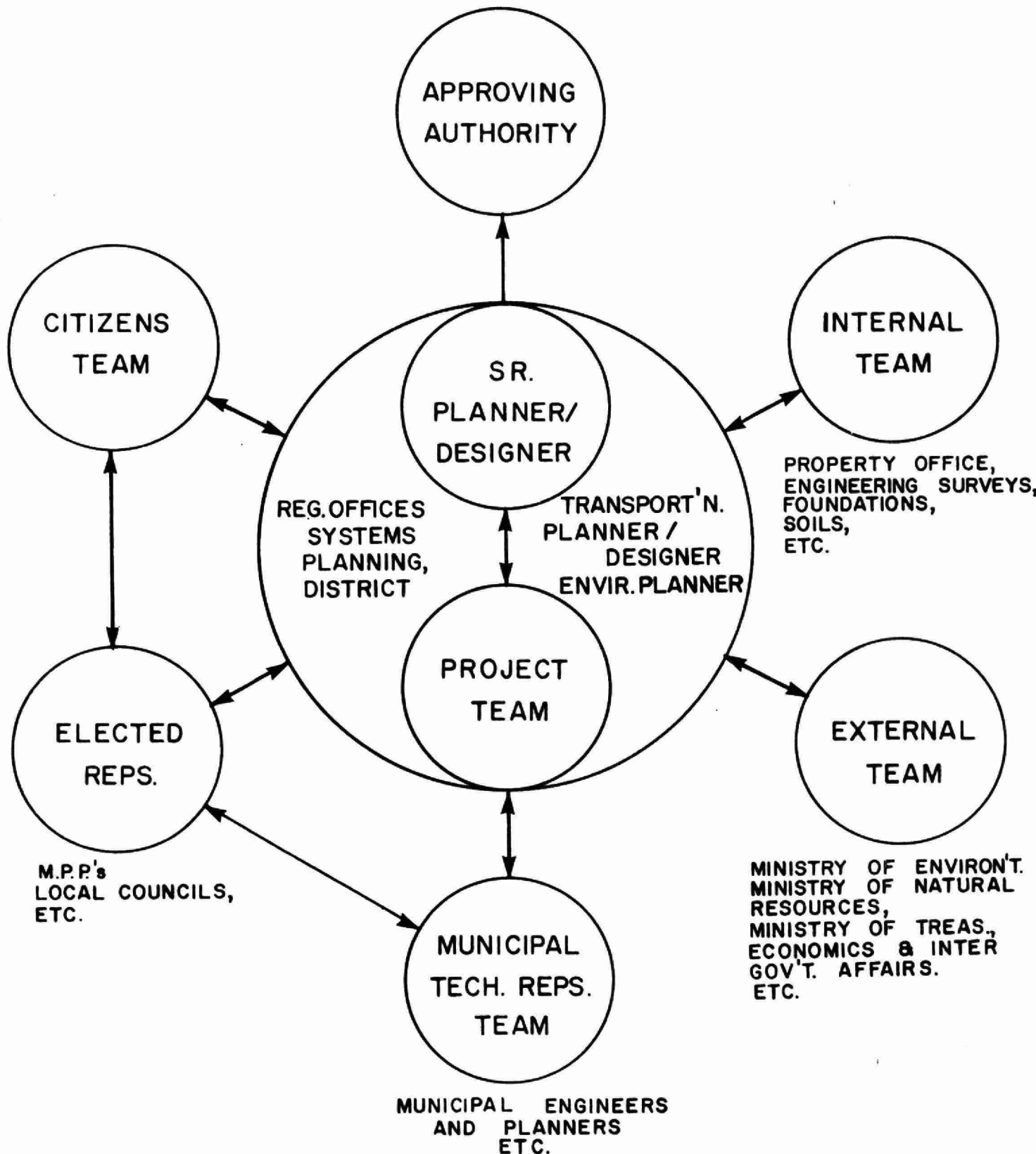
The inter-relationship of the team's components to each other and to the project team is illustrated in Figure VII. A senior transportation planner or designer provides project management. Continuity of development of a project through several stages is achieved by having key members of the project team follow the project through say route location and design.

PRINCIPLE X DEVELOP TECHNICAL ENVIRONMENTAL
PROBLEM SOLVING GUIDELINES; AGENCY-
WIDE STAFF TRAINING PROGRAMS AND
ENVIRONMENTAL ACHIEVEMENT MONITORING
PROGRAMS

Initially the Ministry's Environmental Office provided a consulting service which provided assistance on a job specific basis when potential environmental problems were apparent. More recently a formalized method has been developed with the preparation of guidelines for the project managers' use. The intent is to have the environmental staff continue its consulting function with the view of familiarizing the project manager and his design staff

FIGURE VII

STRUCTURE & RELATIONSHIP OF MULTI-DISCIPLINE TEAM



with the contents of procedural and technical guidelines while in the long term, withdrawing its routine environmental consulting services to concentrate on those jobs which have a more pressing need for such services.

With respect to construction there is recognition of a need for guidelines and more especially a training program identifying those measures that might be applied on a job specific day-to-day basis by construction staff. We have recently embarked upon a program consisting of illustrated talks with our construction staff and the provision of simple booklets outlining more environmentally sensitive field practices.

A CASE STUDY

In order to illustrate the application of several of the foregoing principles a brief summary of the Highway 402 - Strathroy to London study will be presented. This case study will also serve to infer some basic guidelines for environmental assessment of say a proposed industrial plant.

Time does not allow us to illustrate by example the application of all TEN PRINCIPLES. In addition, in our studies we rely very heavily on the use of multi-colour graphical displays to facilitate analysis of information and communication with the public and other members of the project team. Unfortunately these graphics do not lend themselves easily to reproduction in black and white and therefore many will not appear in the printed version of this talk.

The highlights of the study are:

PURPOSE OF THE STUDY

- to find a route for the final link in the 402 Freeway between Sarnia and Highway 401 (a location problem Figure VIII)

HWY. 402 - Designated Alignment

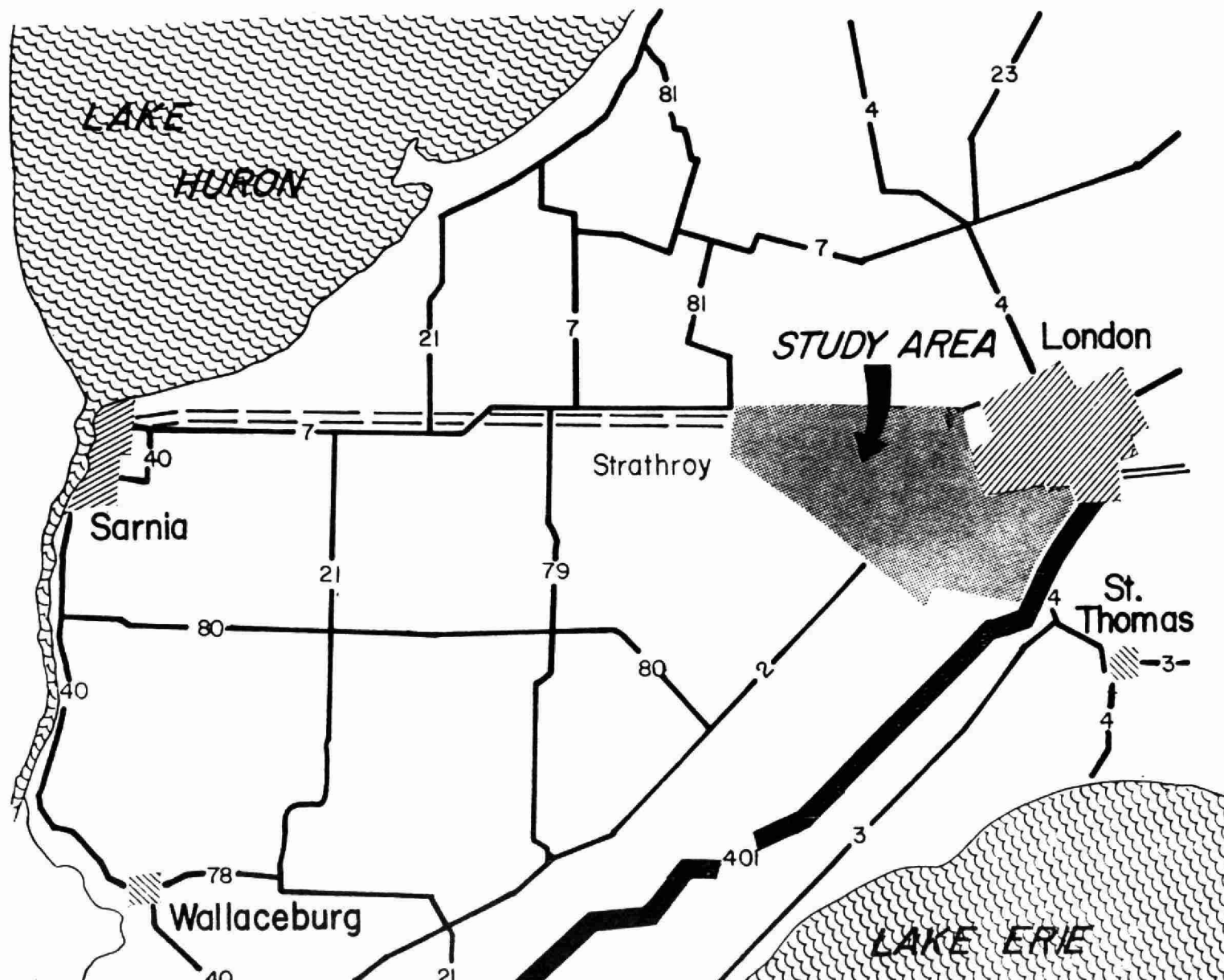


FIGURE VIII

STUDY APPROACH

- . interdisciplinary team comprised of M.T.C. staff and consultants
- . full public participation with meetings and drop-in centres

STUDY PHASES (Programmed)

- . input or data gathering stage
- . analysis and development of alternative routes
- . evaluation of alternatives and selection
- . decision

STUDY PHASES (Actual)

Figure IX illustrates the study phases which actually evolved through the process of environmental studies, transportation planning studies and public involvement. The events leading to this and the key factors leading to a successful completion of the study are listed briefly in the following:

KEY POINTS

- . a pre-study assessment of provincial and regional transportation network requirements and known environmental constraints indicated a study area as shown in Figure X
- . during the Input Phase the public in the study area challenged the need for the freeway, strongly pressed for the expansion of the study area (Figure X) and brought to light a high value outdoor environmental educational area referred to in "The Nelson Report" and located in the centre of the study area (Figure X)
- . the project team re-evaluated a wide range of representative routes including ones to the north and east of London
- . based on a comprehensive analysis of environmental and transportation data the study area was redefined as shown in Figure XI

FIGURE IX

STUDY PROCESS

PUBLIC PARTICIPATION

STUDY PHASE

April 9, 10
18, 19

Public Meetings

Input



June 12, 14
18, 19, 20

Township Councils and Cit. Reps.
Citizens' Meeting
Information Centres

Regional
Corridors
Review

August

Community Survey



October 2, 4
9, 10, 11

Township Councils
Citizen Group Representatives
Information Centres

Route
Alternatives



November 27

Township Councils

Evaluation



January 1974

Information Centres

Route
Selection

Figure X

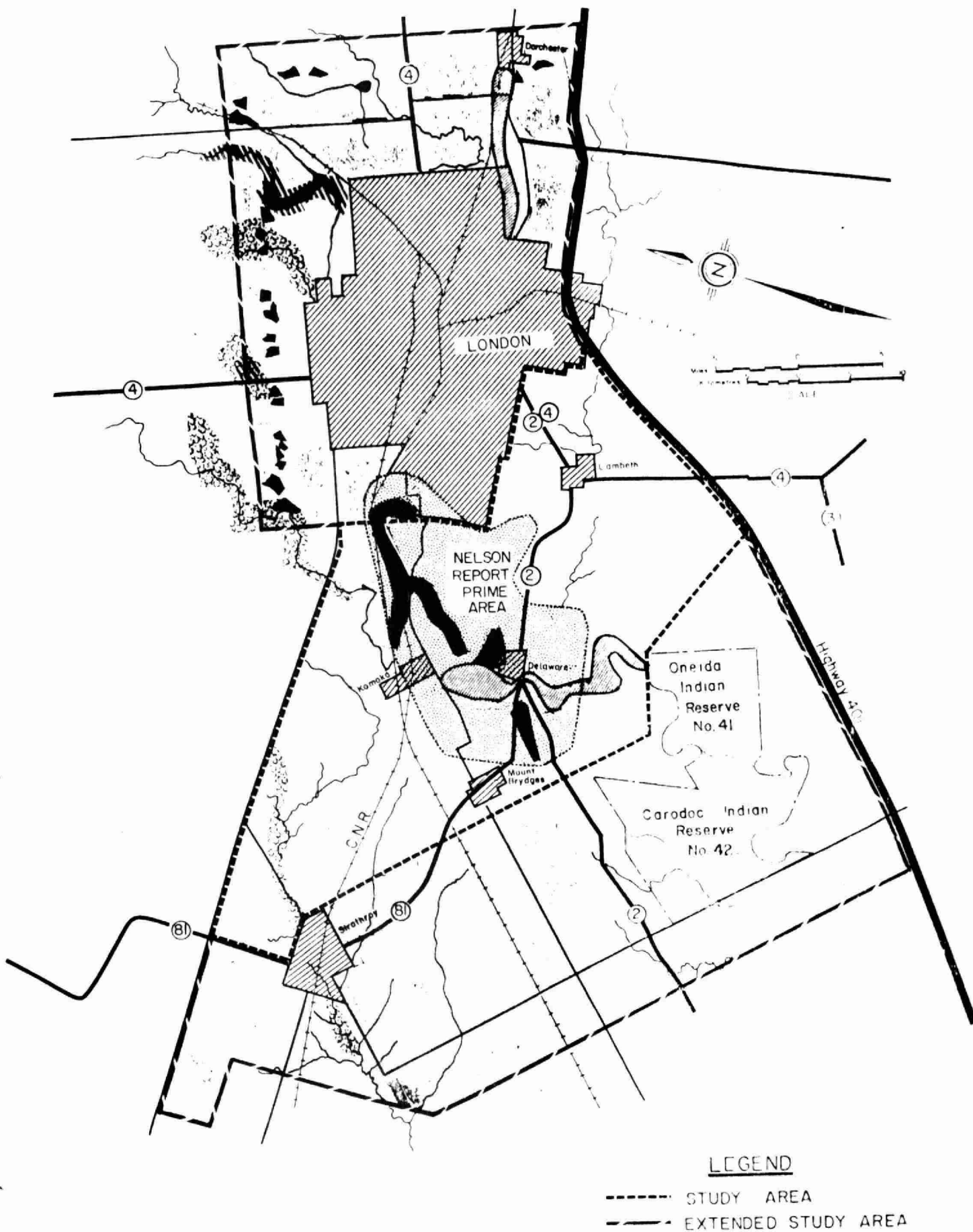
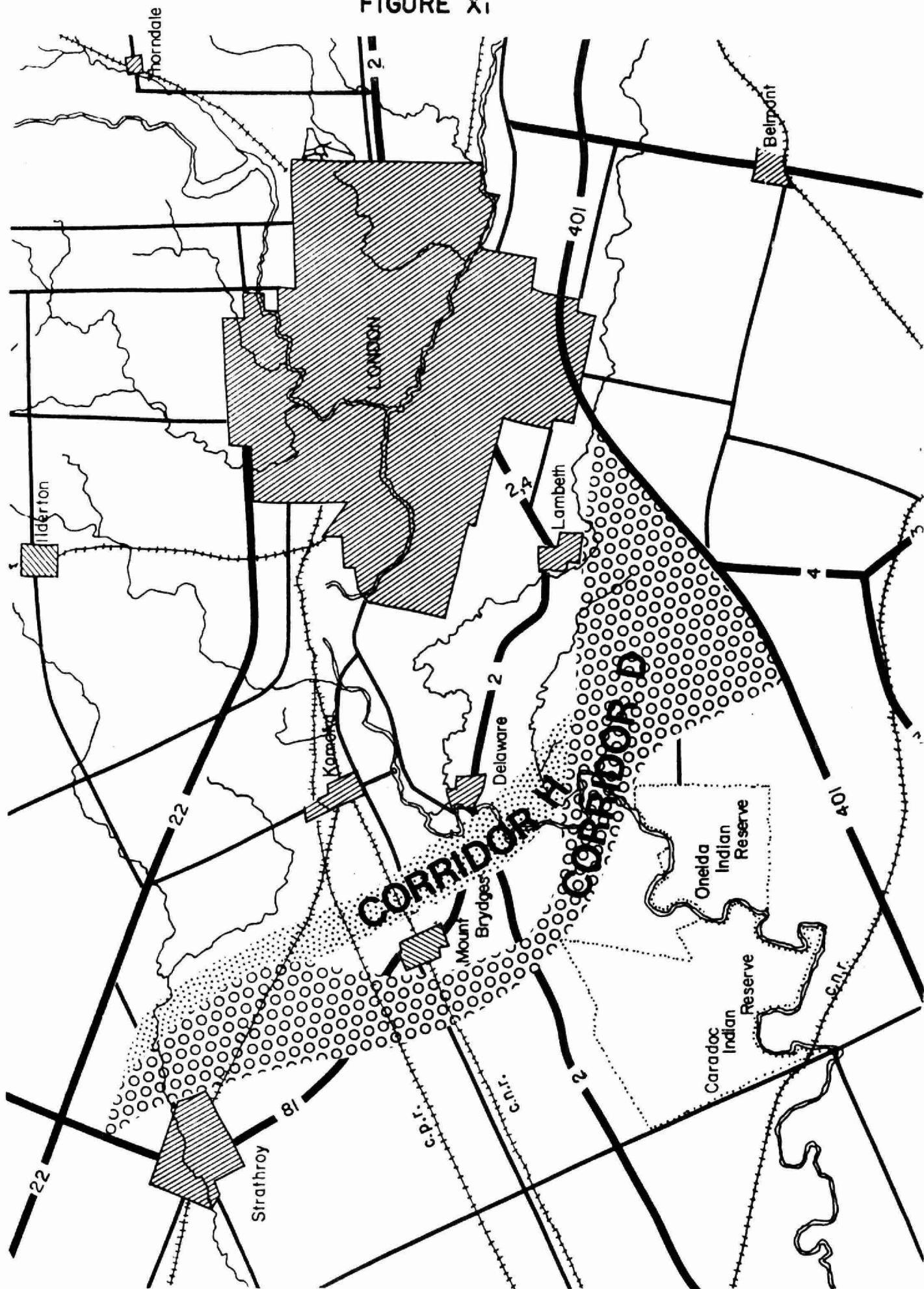


FIGURE XI



CORRIDORS UNDER STUDY

- . a detailed engineering and environmental evaluation of routes shown in Figure XII was conducted
- . assisted by feedback from public meetings, information centres, individual interviews etc. the project team arrived at the recommended route shown in Figure XIII
- . the Minister adopted the recommendation and announced his decision at a press conference in the Study Area
- . the project moved into the Design Phase without further public controversy

THE DESIGN PHASE

- . details of horizontal and vertical alignment, cross-section, drainage and structural designs are now being developed
- . the public directly effected are involved
- . more detailed environmental/engineering studies are underway in relation to ground water impacts, historic and archeological sites, landscape planning, erosion control and protection of the Bald Eagle

SOME BASIC GUIDELINES ON ENVIRONMENTAL ASSESSMENT

Some of the best guidelines for anything are those developed through actual first hand experience or, failing this through observing the effectiveness of others' methods and improving upon them. Some guidelines are explicit in this talk and others are inferred in the case study just discussed. The following very fundamental guidelines are offered in relation to a study to find a location for a new industrial plant, as an example:

1. The study should start or occur at the concept stage of project

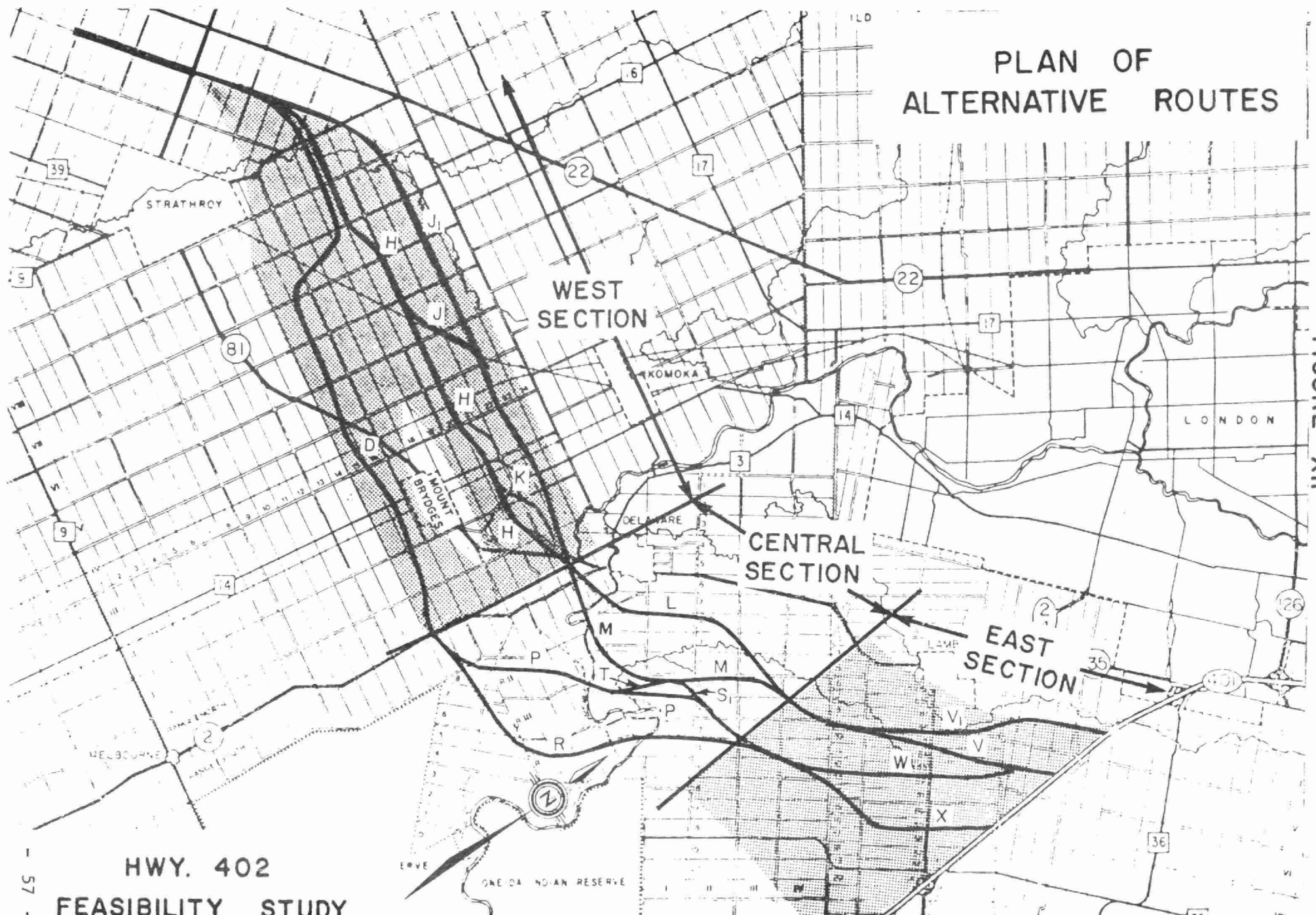


FIGURE XII

HWY. 402
FEASIBILITY STUDY

RECOMMENDED ROUTE
J - L - VI

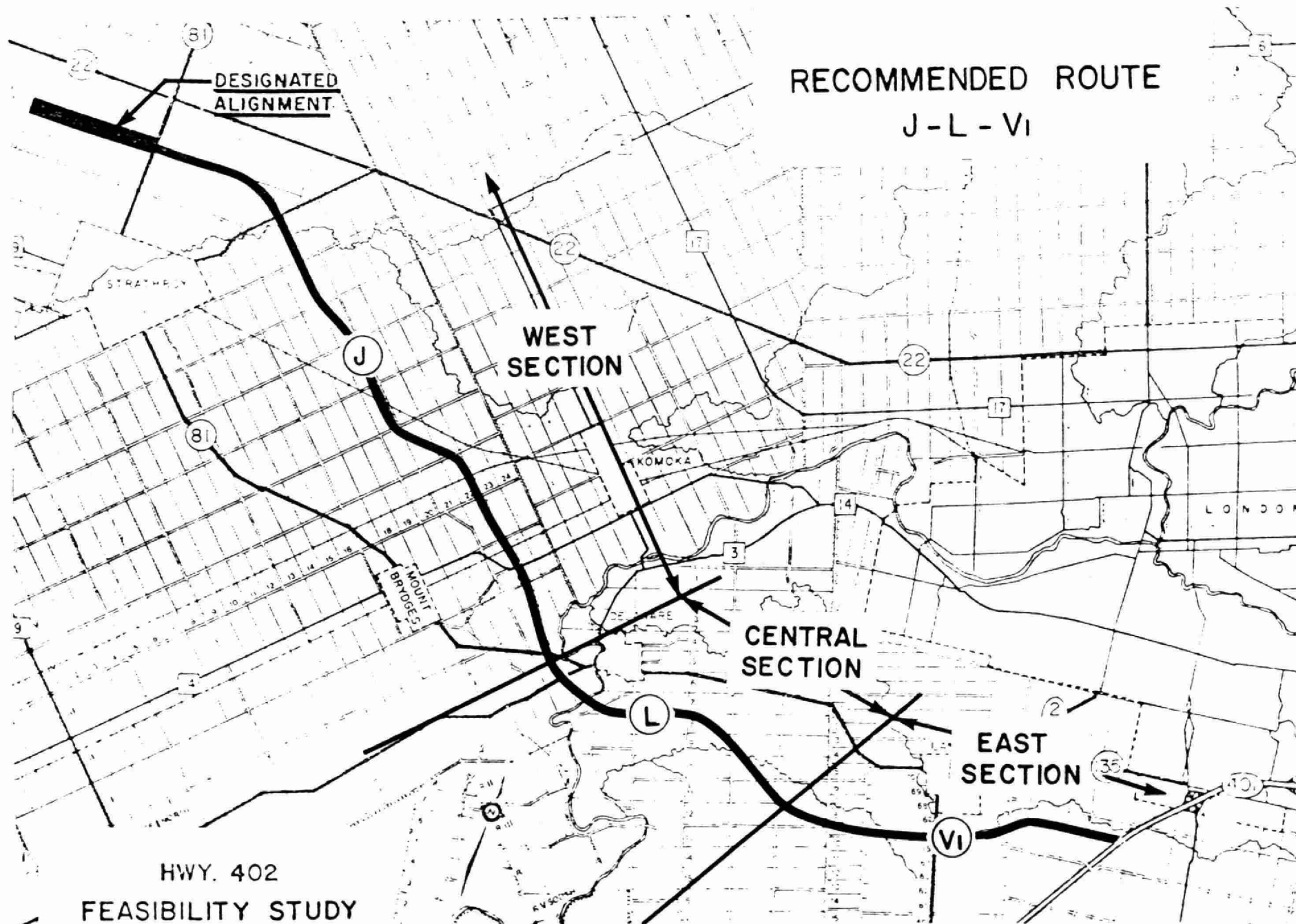


FIGURE XIII

development (at general location stage) when the only locational restraints within the region are those related to Official Plans and Zoning By-Laws.

2. The proponent should have a reasonably firm definition of the project and the options open for dealing with environmental aspects in a tangible way, e.g.

- . economic justification and viability of the plant
- . land requirements
- . terrain and climate restraints
- . general site layouts
- . transportation requirements
- . labour requirements
- . housing and community service requirements
- . raw material requirements
- . industrial process air and water requirements
- . air, water and ground borne emissions

3. The study should consider positive and negative impacts over time e.g.

- . short term/long term
- . during construction and after construction

4. The study should consider direct and indirect impacts (both positive and negative), e.g.

- . consumption of scarce agricultural or forestry land
- . effects of noise and air pollution in the immediate vicinity of project
- . effect of increased employment opportunities within the region

- . stimulus to local and regional economic base
 - . effects of pollutants on chemical and biological qualities of surface waters
 - . loss of fisheries and recreational water bodies
5. The total list of environmental factors should consider both the natural and man-made environment.
 6. The proponent should consider environmental assessment as a means of avoiding environmental problems by adequate planning through to seeking solutions at the design, construction and operation phases.
 - . preventative medicine before start-up, rather than, prescriptive medicine after start-up

THE M.T.C. AND ENVIRONMENTAL ASSESSMENT LEGISLATION

The few brief comments that follow reflect our views as to the success of our voluntary approach and how well our experiences have prepared us for mandatory environmental assessments. Given the relatively short time period that the Ministry of Transportation and Communications has been involved with the present procedures of integrating environmental considerations into our operations, there has been a considerable amount of technical success, political acceptance and a general concurrence on the need for this function within the Ministry.

Within the route planning component, our technical success can be evaluated on the basis that all studies initiated have been taken to completion even though they were often considered to be very environmentally sensitive areas. Many of the projects are now in the design stage and we know that the many restraints identified in the route study are being respected or designed for.

Members of the public have often commended the Ministry and the Minister for introduction of environmental concerns into the planning process. Indeed, the Minister was once commended by a member of one of the opposition parties for his Ministry's approach to environmental studies and public involvement. We have not been forced to accept the null alternative yet.

Lastly, on the issue of extra costs, a survey of projects which included environmental protection indicated that costs ranged from 2 - 4% of the project cost. It is significant to note that in several projects net savings were realized.

Changes in our methods consistent with our experiences and in response to legislation will undoubtedly occur. The large number of new projects added to our construction program annually (500 in 1973) may require some decentralization of our Environmental Office in order to manage the workload effectively.

The amount and methods used for public participation are constantly being reviewed to ensure that our efforts to communicate with the public are adequate and effective. Our goal is to avoid the need for formal "independent hearings". In our view such hearings are a last resort in resolving conflicts. Dialogue and compromise are fundamentally more productive for all.

The Ministry has entered a new era where environmental concerns must be both realistically and sincerely met and we are confident that our course is correct and flexible to meet all contingencies.

CONCLUSION

The issue is clear; mandatory environmental assessments are here to stay. We hope that the ten principles outlined in this paper will serve as stimuli to those organizations who wish to include environmental aims as an input towards achievement of their project development activities. However, to be effective, it will also be necessary to develop within each organization

an environmental consciousness and an environmental staff both of which will assist in identifying and solving environmental problems before they are identified by others.

Should we fail to meet this challenge we will likely end up one day saying as Pogo is alleged to have said, "Gentlemen we have met the enemy, and he is us".

REVERSE OSMOSIS
UTILIZED IN THE ZERO DISCHARGE SYSTEM
AT ROCK ISLAND ARSENAL, ILLINOIS

The ultimate in water pollution control is zero discharge of any wastewater. The Rock Island Arsenal System has been operating since February, 1973, with zero wastewater discharge. The Arsenal is a large metal working facility with numerous plating lines including chromium, cyanide, and copper, and numerous cleaning lines. Machining is also done and soluble cutting oils are often in the waste streams.

The Zero Discharge System installed at the Arsenal includes conventional chemical treatment and clarification. Reverse Osmosis follows the clarifier to economically recycle water and to concentrate the waste salts. Special valves assure that the concentrate salt waste will have the smallest volume possible. The Reverse Osmosis system is the only reason a zero discharge installation is feasible. Without it, the cost for water recycling would have been exorbitant.

by

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He joined Osmonics, Inc., as Applications Engineer in 1971, after working with Honeywell Inc., for five years in Product Development and Pollution Control.

Osmonics, Inc., manufactures Reverse Osmosis and Ultrafiltration Membranes and Modules as well as equipment for water purification and waste treatment.



REVERSE OSMOSIS ZERO-EFFLUENT SYSTEM
(Case History of Rock Island Arsenal System)

by

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The ultimate in water pollution control is zero-discharge of liquid effluent. This concept requires that the waste water be purified to the extent that it can be continuously recycled to the process and the pollutants be concentrated to a dry form for disposal. Conventional chemical treatment and clarification do not provide sufficient purification to allow recycling of the water in a typical metal finishing operation since there will be a build-up of soluble salts, particularly sodium salts of sulfate and chloride in the water. Reverse osmosis provides the only economical method of concentrating these soluble salts and recovering the purified water by recycling.

The Rock Island Arsenal in Rock Island, Illinois, has been operating with a Zero-Effluent System since February, 1973. This system handles the combined liquid wastes from metal finishing operations including hard chromium plating, chromic acid anodizing, copper cyanide, cadmium cyanide, nickel and black chromium plating, and associated cleaning tanks as well as alkaline derusters and paint strippers.

The Zero-Effluent System consists basically of conventional chemical treatment for chrome and cyanide, followed by clarification with the clarifier sludge going to centrifuges for dewatering and then incineration. The incinerator yields a dry product of sintered, metallic oxides.

The clarified water is processed by dual reverse osmosis units to concentrate the remaining salts while covering a high percentage of the clarifier effluent as purified water for recycling. Special control valves are used to assure minimum volume of concentrate and maximum recovery of pure water regardless of variations in feed water concentration.

The concentrated liquid from the reverse osmosis system then goes to a mechanically aided evaporator which takes this final waste to a dry salt form.

The following discussion will explain the various sub-systems for the total Zero-Effluent System. Items are described in the order of the flow of water through the system. There was no effort made to reduce rinse rates or to change the procedures used for metal finishing prior to installation of the waste system. This system was merely "added to the end of the waste water pipe".

The rinse waters and process tank dumps flow into one of two underground collection sumps. The cyanide rinse waters are treated prior to entrance into the underground sumps. The cyanide waste is chlorinated to oxidize the cyanide to cyanate. The cyanate containing waste then flows to the sump tank and is mixed with the other wastes.

The waste solution is pumped from the sumps to the neutralizing section of the clarifier. The clarifier tank is divided with about 10% being used for the neutralization section, which consists of three separate 100 gallon tanks. In these tanks automatic pH and ORP instrumentation controls the addition of sulfuric acid, sodium hydroxide, and sodium hydro-sulfite for neutralization and chrome reduction. The chemical holding tanks are mounted above the neutralization tanks to allow gravity feed of chemicals. Mixers with 2 Hp motors are used to continuously agitate the solution. In the effluent from tank 2 the hexavalent chrome has been reduced to trivalent and the pH is approximately 8.0. A polyelectrolyte flocculant is added in the third tank.

Leeds and Northrup proportional controllers were used initially for pH and ORP. These controllers were subject to malfunction due to surges of acid, alkali, or chrome entering the treatment tanks or due to electrical power interruptions. The proportional controllers have now been replaced with on-off control of solenoid valves on the chemical holding tanks.

The neutralized waste solution overflows into a 50,000 gallon clarifier tank which is 40 feet long, 18 feet wide,

and 12 feet high. Metallic hydroxides and other insoluble compounds settle to the bottom and relatively clear liquid overflows by a weir to the holding section of the clarifier tank for subsequent reverse osmosis treatment. A bridge crane with a 3 Hp motor travels the length of the clarifier. In one direction a paddle skims oil and debris from the surface and in the other direction it scrapes the precipitated sludge into a collection trough.

Sludge from the clarifier is pumped to a holding tank and then to dual Barrett centrifuges with 2 Hp motors for dewatering. Watery metal hydroxide sludge at 1-2% solids is increased to 15-20% solids (tooth-paste consistency). The separate liquid is returned to the clarifier.

From the centrifuge the sludge is auger-fed to a multiple-hearth furnace manufactured by Mine Smelting, Inc. This incinerator operates at 400-450°F. burning waste oil from the Arsenal and drying the sludge to sintered, metallic oxides. The metallic oxide powder is conveyed to a hopper outside the building and held for land fill disposal or for resmelting. The incinerator has a power requirement of 10 Hp. Exhaust gases from the incinerator go through a fume scrubber where a 35 gpm water jet removes air borne impurities. The scrubber water is recycled to the clarifier. Arsenal personnel report that oversizing of the furnace has resulted in low usage and that complex controls have made consistent operation difficult.

The liquid effluent from the clarifier is pumped from the overflow tank through GAF bag filters rated at 25 microns. This water is usually quite low in suspended solids and filters normally run 5-10 shifts between changes. In a few cases, due to the pH fluctuations in the clarifier tank, the turbidity increased enough to require filter changes every 4-8 hours.

This filtered water is then pH adjusted with sulfuric acid to 5.5-6.0 and fed to dual Osmonics reverse osmosis (R.O.) units each rated for 50 gpm permeate. At the inlet to the R.O. units the water is filtered through 25 micron wound filter cartridges manufactured by Commercial Filters Corporation. The solution is then pressurized to 400 psig using Goulds multi-stage centrifugal pumps with 40 Hp motors and distributed to the OSMO[®] reverse osmosis modules.

In reverse osmosis the pressurized solution flows over the surface of a porous plastic membrane. The pressure transfers pure water through the membrane pores while most salts and organics are retained (rejected) and concentrated on the feed side of the membrane. The feed water is separated into two streams, concentrate (or rejected materials) and permeate (or pure water).

These machines use the spiral wound or scroll configuration R.O. membrane module manufactured by OSMONICS, INC. Membrane sheets are spirally wrapped around a PVC permeate tube and a plastic mesh screen separates the membrane layers. This screen provides finite spacing between the membrane layers and creates turbulent flow at the membrane surface to minimize concentration polarization and fouling. The spiral modules are installed in series with each other in pressure vessels and the vessels are arranged in a series-parallel combination for optimum flow conditions.

The R.O. units at Rock Island Arsenal are designed to obtain maximum concentration of salts and maximum recovery of pure water (permeate). Because of expected fluctuations in feed water concentration these machines were designed with Osmonics' patented Automatic Linear Feedback Control Systems (ALFC). The ALFC can be set to give a specific concentration of salts in the concentrate stream regardless of feed water concentration. This particular ALFC system uses conductivity monitors, pressure transducers, and pneumatic valves to adjust flow through the concentrate and recycle plumbing. The ALFC will automatically recycle all solution through the modules until a preset concentration has been reached. At that time, the concentrate valve will open slightly and recycle valve will close slightly allowing some concentrate to leave the machine. These valves are automatically adjusted on a continuous basis in order to maintain the present concentration. During typical operation the feed water is 500-1000 ppm. The permeate is recycled to the process rinse tanks. Normally 98% of the total flow is recovered as permeate for re-use and 2% of the feed flow from the clarifier carries the concentrated salts.

There have been a number of bearing problems on the multi-stage centrifugal pumps and the Arsenal reports that the pump manufacturer was very slow in delivering replacement parts and would not allow warranty consideration on the defective items. Stainless steel tubing on one R.O. unit developed pinhole corrosion within the first year and was replaced by Osmonics. It was suspected that stray electrical currents may have caused corrosion since it was not a problem on the second unit. Definite cause of this corrosion problem has not been determined.

The R.O. units have operated for over 28 months with no module replacements. During this period of time, the modules have been chemically cleaned only 3 times. The main reason for the low frequency of cleaning is that introduction of chemical cleaners into a closed-loop system such as this may lead to contamination problems. However, performance of these units has been very good and frequent cleaning has not been required. There have been no problems in using the recycle water.

The feed water to the R.O. units is not a perfectly clear solution but is relatively low in turbidity. A Millipore fouling test was run on the feed water and it was found that the "fouling index" was 98% on a sample taken after the bag filters. Even with this high "fouling index" the R.O. modules have shown no signs of plugging or excessive fouling. It is felt that the highly turbulent conditions over the membrane in the spiral wound modules keep the undissolved compounds in suspension and allow them to be carried to the evaporator in the R.O. concentrate.

The concentrate from the R.O. units is pH adjusted to 7.5 and evaporated to dry salts using an Artisan rotary-blade evaporator. The evaporator is designed to produce a dry product by using blades which wipe the outer surface of the evaporator to prevent solids build-up. Steam at 30 psi pressure is used to heat the evaporator and an electric motor of 20 Hp runs the wiper blades. The evaporator has operated satisfactorily but does not consistently produce a dry salt.

When design of this waste treatment system began in 1968, the objective was to reduce water consumption and meet anticipated effluent guidelines. The zero-effluent approach was chosen as the most practical approach to achieve these objectives.

Since the U.S.A. was at war during the Arsenal's design period, the system was designed for nearly twice the water flow it is now handling. Some excess capacity was also designed into the system to meet peak water usage during a "national emergency". The remaining excess capacity is due to reduced work load at the Arsenal. As of June 1975, the system had been operated for approximately 8 hours per day handling about 25,000-30,000 gallons of waste water per day over a 28 month period.

The Arsenal Waste Water System is operating as it was designed and the start-up problems were not of abnormal scope. The instruments have been changed slightly, the clarifier has performed well, the original R.O. modules are still in use, and the ALFC on the R.O. unit has performed extremely well, the evaporator has performed satisfactorily, the centrifuges are doing well and the incinerator has performed satisfactorily. Waste water is being recycled continuously and there is no liquid effluent. The system truly meets the goals that the Arsenal set for the system: reduced water consumption and recovery of pollutants in dry form for land disposal. Most of all, the system has shown the feasibility of zero water discharge for a manufacturing facility.

PROBLEMS ASSOCIATED WITH ACTIVATED SLUDGE
TREATMENT OF KRAFT BLEACHERY EFFLUENT

Although activated sludge systems are used in the treatment of pulp and paper mill effluents, many problems associated with their design and operation have not been identified. Extensive bench-scale and pilot-scale experimentation involving activated sludge treatment of kraft bleachery effluent have revealed a number of important problem areas.

On-site pilot-scale operation showed that activated sludge systems were not capable of reducing toxicity to meet the effluent regulations. Results of subsequent studies carried out in laboratory bench-scale reactors indicated that toxicity could consistently be reduced to an acceptable level by activated sludge systems operated under the same loading conditions. The increased toxicity removal capabilities were attributed to the homogeneous characteristics and reduced toxicity of the feed solution. Bioassay testing provided a measure of the extent of detoxification of untreated bleachery effluent during storage at various temperatures and pH's.

by

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FACTORS AFFECTING ACTIVATED SLUDGE

TREATMENT OF KRAFT BLEACHERY EFFLUENT

by

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Wastewater Technology Centre
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INTRODUCTION

Biological treatment systems have been used extensively in the treatment of kraft mill effluents in Canada and United States. The most widely accepted system is the aerated stabilization basin (1) (2), which has proven to be quite successful in the reduction of BOD_5 , suspended solids and toxicity. A review of the literature (3) revealed that only a limited number of activated sludge systems have been employed in the treatment of kraft mill effluents and that detailed information on their toxicity reduction capabilities was not available. As a result, the Technology Development and Demonstration Division of the Environmental Protection Service, at the Wastewater Technology Centre, Burlington, Ontario, conducted a multi-objective program involving activated sludge treatment of kraft bleachery effluent (KBE). Initially, a bench-scale study was carried out to evaluate the suitability of a two-stage activated sludge process for the treatment of this particular wastewater; its performance was compared with a conventionally operated single-stage activated sludge unit. Results indicated that BOD_5 and suspended solids removal were within an acceptable range. Although reliable toxicity results were limited, they were sufficiently encouraging to warrant a pilot-scale field project. Consequently, a study was initiated at Eddy Forest Products Ltd., Espanola, Ontario, involving the operation of two pilot-scale activated sludge treatment systems to compare toxicity removal between a two-stage and a single-stage system. Results (4) showed that the two-stage activated sludge system was capable of greater toxicity reduction than the single-stage system. Increased toxicity removal was achieved during periods when the organic and volumetric loadings to the two-stage system were much higher than for the single-stage unit. However, effluents from both systems did not meet the toxicity requirements specified in the Pulp and Paper Effluent Regulations (5); i.e., there must be 80% survival of rainbow trout for 96 hours in a 65% test solution.

Prior to completion of the field study, preliminary tests were conducted on both untreated and biologically treated effluents to establish whether it was feasible to use physical-chemical treatment for toxicity reduction. Results indicated that a substantial detoxification of KBE was obtained through the addition of powdered activated carbon and aluminum sulfate. Studies carried out by the Pulp and Paper Research Institute of Canada (6)

using a physical-chemical process which utilized these chemicals showed that the toxicity of the KBE could be reduced to the level specified in the effluent regulations (5); however, the BOD_5 was not significantly reduced. As a result, an experimental program was set up to evaluate a combined physical-chemical and biological treatment system which had potential for simultaneous BOD_5 and toxicity reduction. Studies were carried out at the Wastewater Technology Centre, Burlington, in bench-scale reactors operated under similar loading conditions as in the on-site pilot-scale operation. In contrast to results of the field study (4), the bench-scale activated sludge reactors, even without chemical addition, produced effluents which generally met the regulations (5). The experimental program was revised to investigate factors related to the detoxification of KBE. The study was also extended to evaluate the temperature effect on the performance of an activated sludge system because treatment of KBE at high temperatures has been identified as a major problem in the pulp and paper industry (7).

The objectives of the revised experimental program were to investigate the factors which affect the toxicity of KBE; to determine the effect of elevated wastewater temperatures on the treatment efficiency of activated sludge systems; to provide methods of correction for the operational problems encountered; and to establish the highest practicable operating temperature for an activated sludge system treating KBE.

MATERIALS AND METHODS

The experimental program was divided into two areas. The first dealt with the reduction of the toxicity of KBE samples stored at various pH's and temperatures; the effects of aeration, aeration rate and nutrient concentration on the toxicity were also investigated. The second involved the operation of single-stage activated sludge systems treating KBE at temperatures ranging from 22 to 38°C.

KBE from the six-stage CEHDED bleach plant No. 2, at Eddy Forest Products Ltd. was used for the study. The mill presently processes hardwood and/or softwood at a production capacity of 650 ADT of pulp per day. On the average, 375 tons of kraft pulp are bleached in the No. 2 plant with a wastewater flow of approximately 11 m³/min (2,500 Igpm). Results of the field study (4) showed that effluents produced during the bleaching of softwood were consistently more toxic than those produced from hardwood pulp.

As the experimental program was initially designed for the evaluation of toxicity removal capabilities of an activated sludge system, the KBE with the higher initial toxicity was desirable. Arrangements were made so that samples were collected only when the mill was processing softwood.

KBE was trucked from Espanola to Burlington in polyethylene lined 200 litre barrels. Upon arrival, the pH in each barrel was adjusted to approximately 8 with sodium hydroxide. The contents of the barrels were pumped into a 5,500-litre refrigerated storage tank with temperature controlled at 4°C.

The untreated wastewater was pumped to a 50-litre storage tank located in the laboratory and equipped with heating and mixing units. After the temperature was raised to approximately 22°C and nutrient added, the KBE was fed to bench-scale activated sludge reactors.

Initially, this sample handling procedure was considered to be adequate for obtaining a KBE quality comparable with that used for the on-site pilot-scale study. However, as will be discussed later, storage of the neutralized KBE resulted in significant detoxification. Consequently, the above sample handling procedures were revised. Unneutralized samples were mixed, as stated previously, to obtain homogeneous effluent characteristics and stored in barrels at room temperature. pH adjustment and nutrient addition to the waste in individual barrels was not carried out until the barrel was going to be used. Analytical results indicated that KBE could be stored in this manner for up to 2 weeks without significant change in effluent quality. The variation in pH, BOD₅, TOC, suspended solids and toxicity over the 14-day storage period were within the limits of experimental error of the analytical determinations.

A comprehensive analysis of KBE was made for each shipment. Results shown in Table 1 were based on the analyses of 10 homogeneous samples prior to pH adjustment and nutrient addition. There was considerable variability in the wastewater characteristics even when KBE for the studies was collected only during the processing of softwood.

TABLE 1 Characteristics of Kraft Bleachery Effluent

	<u>Range</u>	<u>Average</u>	<u>Standard Deviation</u>
pH	2.3-3.9	3.1	0.7
BOD ₅ (mg/l)	80-230	150	46
SS (mg/l)	30-79	50	14
TOC (mg/l)	190-600	390	120
COD (mg/l)	910-1570	1130	355
TDS (mg/l)	1640-3100	2560	460
TKN (mg/l)	1.5-2.8	2.0	0.4
TP (mg/l)	0.1-1.7	0.8	0.7

BOD₅ Refers to unfiltered 5-day Biochemical Oxygen Demand

SS Suspended Solids

TOC* Total Organic Carbon

COD Chemical Oxygen Demand (unfiltered)

TDS Total Dissolved Solids

TKN* Total Kjeldahl Nitrogen

TP* Total Phosphorus

*Unless specified otherwise samples were filtered.

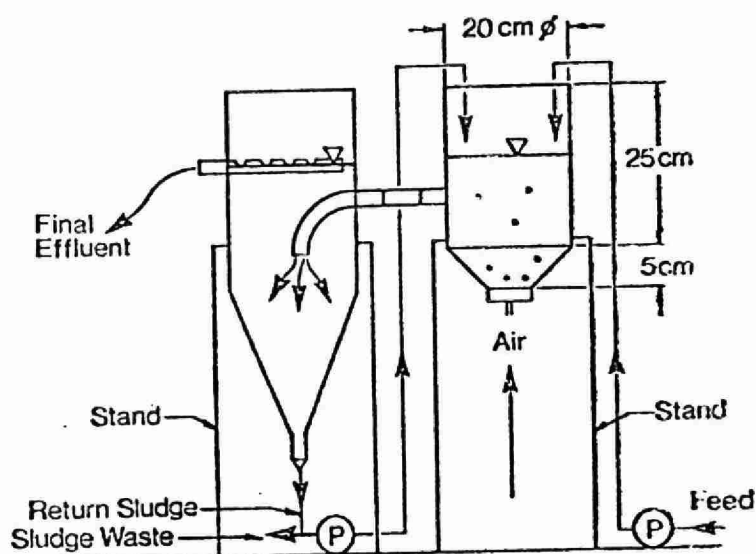


Fig. 1 BENCH-SCALE ACTIVATED SLUDGE REACTOR

The reactor used for the single-stage operation is shown in Fig. 1. It consists of a 5-litre aeration cell and an 8.5 litre clarifier, both made of acrylic plastic. Compressed air was introduced into the reactor through a fritted glass diffuser in the base of the aeration cell. This provided adequate mixing and a dissolved oxygen concentration greater than 3 mg/l for all laboratory experiments. Feed and sludge recycling facilities were controlled by variable speed peristaltic pumps. Sludge used for seeding the bench-scale reactors was taken from the Burlington Skyway Sewage Treatment Plant. Following acclimation of the biological system, 24-hour refrigerated composite samples of influent and process effluents were collected for analysis. Upon revision of the experimental program toward the investigation of temperature effect on the performance of the activated sludge system, liquid temperature in the reactor was controlled by the installation of a 100-watt submersible thermostatic heater.

BOD₅, COD and suspended solids analyses were performed according to procedures specified in Standard Methods (8). Influent, effluent and mixed liquor suspended solids determinations were carried out using glass fibre filter papers (Gelman Type A). TOC's were determined using a Beckman Infrared Carbon Analyzer. Total Kjeldahl nitrogen, and total phosphorus were analyzed by wet chemical colourimetric techniques according to methods specified by Technicon Instruments Corporation.

Bioassays were performed on untreated wastewater and effluents from the activated sludge systems to evaluate the process toxicity reduction capabilities. Juvenile rainbow trout (Salmo gairdneri) were used for the bioassay. Test procedures were the same as the methods described in the report of the pilot-scale study (3). Due to the limited amount of KBE available for testing, only static bioassays were carried out. Median survival time (MST) was used as the parameter to measure toxicity reduction. All bioassays were performed at $15 \pm 1^{\circ}\text{C}$ on 100% test solutions. Compressed air was supplied at 250 ml/min to keep the dissolved oxygen level at greater than 8.0 mg/l. While untreated KBE required neutralization, biologically treated effluents were all within an acceptable pH range for bioassay testing.

FACTORS RELATED TO THE DETOXIFICATION OF KRAFT BLEACHERY EFFLUENT

As stated previously, operation of laboratory bench-scale reactors

under similar conditions as the on-site pilot-scale study resulted in a substantial improvement in toxicity reduction. Routine bioassays carried out to monitor the performance of treatment systems indicated that the increased detoxification capabilities of the bench-scale reactors was partially due to the handling and storage of KBE. Consequently, an experimental program was designed to examine factors affecting the toxicity of KBE during storage. Parameters investigated include pH, storage temperature, duration of storage, aeration rates and nutrient addition.

Effect of pH and Temperature

The effect of pH adjustment and storage temperature upon the toxicity of KBE was carried out using an unneutralized pre-mixed homogeneous effluent sample. Four barrels were stored at room temperature at pH values of 2.3, 4.0, 6.5 and 8.0 respectively. An additional four barrels with similar pH's were stored in a 4°C temperature controlled room. Except for the barrels with a pH of 2.3 which was the original pH of the KBE, adjustment of pH to the higher values was carried out using 50% NaOH solution. Bioassays were performed over an 11-day storage period. The MST values at each pH and temperature are plotted in Fig. 2.

The graphs show that the storage of KBE at higher pH values results in a considerable reduction in toxicity. For samples with pH equal to or less than 4.0, the change in toxicity during the 11-day storage period was negligible. Statistical analyses showed that there was no significant difference in toxicity between the two storage temperatures for each pH level. The insignificant effect of storage temperature on toxicity is further illustrated in Table 2 which shows results of bioassays carried out on two sets of unneutralized KBE during a 10-day storage period at 4°C and room temperature (22°C).

Walden et al (9) also reported that there was no significant difference in toxicity between samples stored at 8 and 25°C and suggested that storage of KBE at low temperatures offers little or no additional advantage except where anaerobiosis might occur. In a previous study, Howard and Walden (10) found little change in toxicity for sockeye salmon following 2 days storage of neutralized KBE at 2°C; in 5 days of storage, the 96-hour LC50 increased from 29 to 46%. Sprague and McLeese (11) have reported that during the storage of neutralized bleached kraft mill effluent (BKME) for one week, the MST increased from 2.5 to 66 hours in a 100% test solution; no mortality in 96 hours was observed after a two-week storage period.

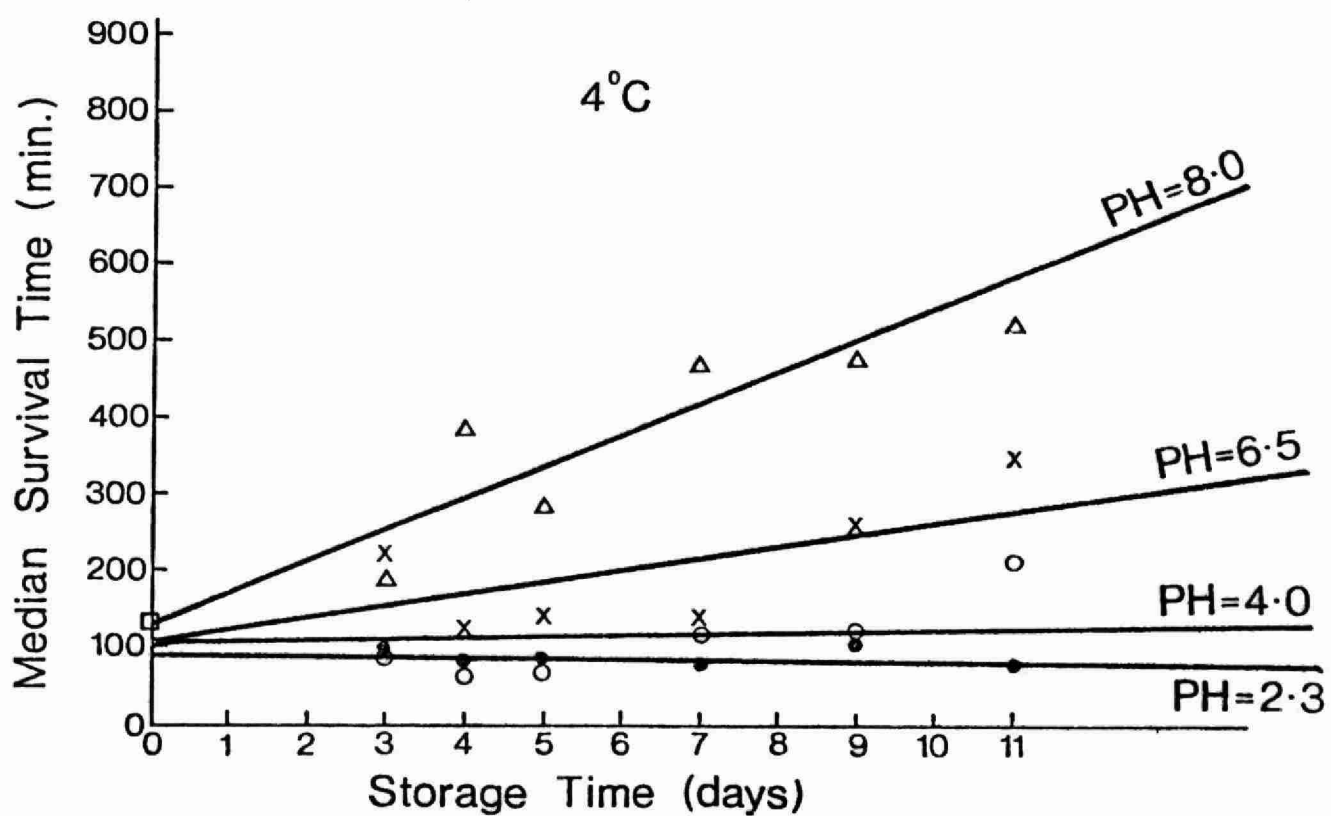
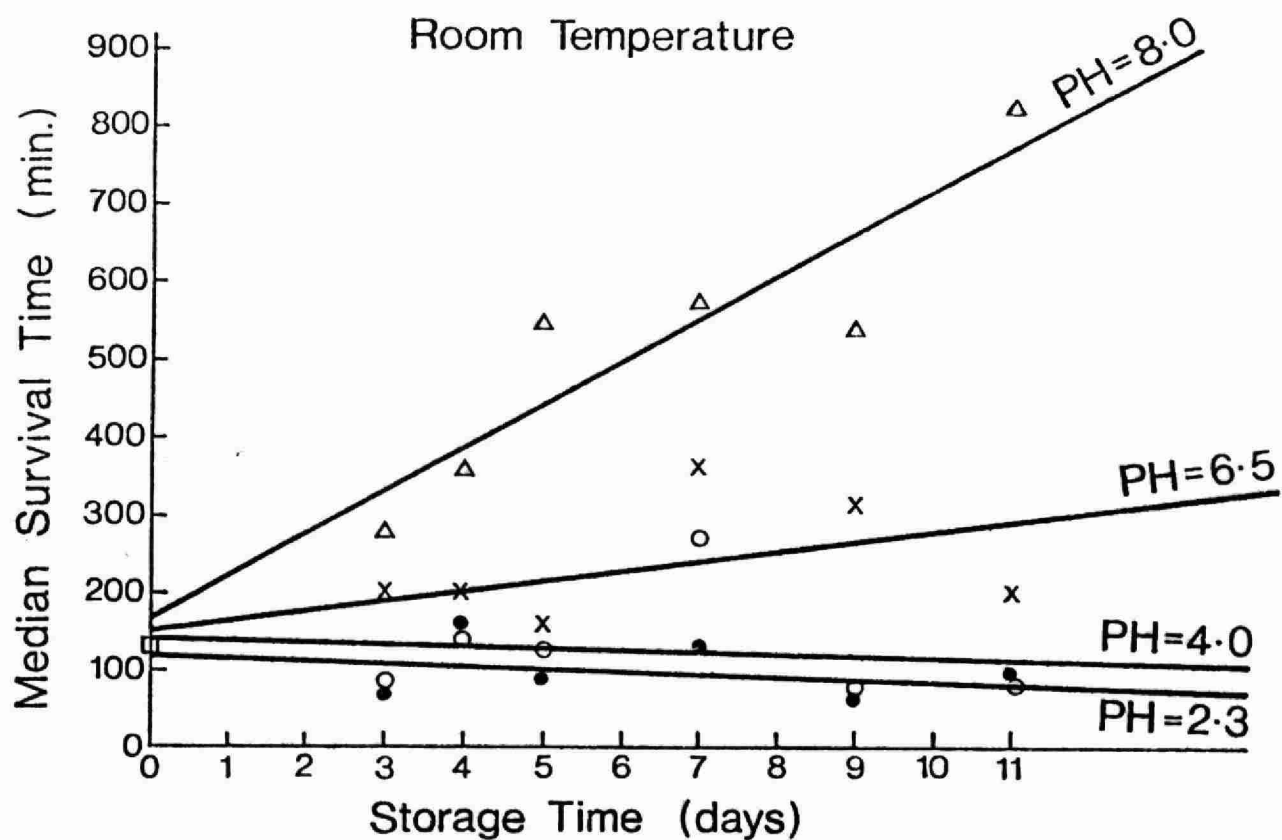


Fig. 2 EFFECT OF PH ADJUSTMENT AND STORAGE TEMPERATURE ON TOXICITY

Table 2 Change in Toxicity During Storage

Sample A					Sample B				
Storage	4°C		Room Temperature (22°C)		4°C		Room Temperature (22°C)		
	MST	95% Confidence Limit	MST	95% Confidence Limit	MST	95% Confidence Limit	MST	95% Confidence Limit	
(days)	(min)	(min)	(min)	(min)	(min)	(min)	(min)	(min)	
0	--	--	165	130-200	--	--	415	360-460	
1	115	100-145	205	185-230	490	410-575	490	410-575	
2	150	140-160	190	170-215	--	--	--	--	
4	--	--	--	--	485	410-580	485	410-580	
5	170	155-190	320	295-345	--	--	--	--	
6	--	--	--	--	410	360-475	390	340-440	
7	160	140-180	215	200-225	--	--	--	--	
8	305	280-340	205	190-225	--	--	--	--	
9	310	280-340	215	190-235	--	--	--	--	
10	--	--	--	--	255	235-285	460	425-500	

Effect of Aeration Rate at Neutral pH

To investigate the effect of aeration rates on the toxicity of KBE, four samples taken from the same barrel were neutralized and aerated at 0.5, 1, 2 and 3 l/min. Aeration resulted in the generation of foam which was skimmed from the surface at 30 minute intervals. Aeration of the samples continued for 5 hours before bioassays were started. Results presented in Fig. 3 indicate that the MST increases as aeration rate increases. Although the mechanism for the resulting detoxification was not investigated, it was considered that this could be attributed to any one, or a combination of the following; i.e., stripping of volatile toxic substances to the atmosphere and removal of toxicants by foam fractionation. Ng et al (12) in the study of process parameters of foam separation for detoxification of bleached kraft mill effluent also reported that aeration rate was a factor responsible for toxicity reduction.

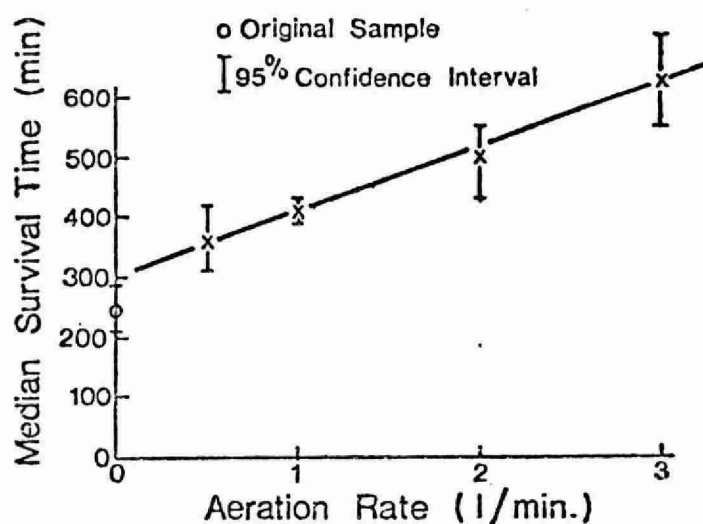


Fig. 3 EFFECT OF AERATION RATES ON TOXICITY.

Effect of Different pH Levels on Samples Aerated for 5 Days

Results presented above indicate that for an aeration period of 5 hours, the aeration rate has a minimal effect on the rate of detoxification of KBE. To determine whether a long period of aeration had a significant effect on toxicity reduction, six 25-litre batch reactors were filled with KBE from the same barrel. pH's of samples in each reactor were adjusted according to the values shown in Table 3. In one reactor, 100 mg/l of biomass was added to simulate the condition of an aerated stabilization basin. One sample was filtered through filter papers in an attempt to minimize biological activity in the reactor. All reactors were set-up in a laboratory at room temperature and aerated continuously at a rate of approximately 2 l/min. After 5 days of aeration, the pH was adjusted to 7.5 and the bioassays were initiated.

TABLE 3 Effect of Different pH Levels on Samples Aerated for 5-Days

Reactor No.	pH Adjustment	Results	
		MST(min)	95% Confidence Limit
1*	2.5	220	196-246
2	4.0	430	350-529
3	7.5	>5760	-
4**	7.5	>5760	-
5***	7.5	>5760	-
6	12.0	>5760	-

* original sample, no pH adjustment

** seeded with 100 mg/l of biomass taken from the bench-scale activated sludge reactor

*** sample was filtered through Whatman No. 40 paper to remove suspended solids

Results presented in Table 3 showed that after aeration at a rate of 2 l/min for 5 days, there was no mortality in 96-hours in samples with the pH adjusted to a value equal to or greater than 7.5. Samples without pH adjustment and with pH adjusted to 4.0 were still extremely toxic with the MST being 220 and 430 minutes, respectively. This suggests that for neutralized samples, a long aeration period affects significantly the ex-

tent of detoxification and is confirmed by comparing results presented in Fig. 2 and Table 3. The MST of a sample stored without aeration at a pH of 8 for 5 days was approximately 430 minutes. Under similar storage conditions with 5-days aeration, there was no mortality after a 96-hour test period; thus, it can be concluded that aeration increases the rate of detoxification. It should be noted that the 96-hour bioassay test is a continuation of treatment by aeration and this must be taken into consideration when interpreting the bioassay results.

The complete detoxification of the samples which had been filtered to minimize bacterial activity and also the sample having the pH adjusted to 12, led to the conclusion that toxicity reduction was not due to biological oxidation alone. Although reaction rates were not measured, it is considered that the chemical reactions which occurred during the storage period were primarily responsible for detoxification. This explains why an activated sludge system successfully removes BOD_5 but fails to remove all of the toxicity. This is of considerable practical importance in selecting a treatment process for the detoxification of KBE and provides an explanation for the better detoxification capabilities of an aerated stabilization basin (13)(14) versus the conventional activated sludge process (3).

Effect of Nutrient Addition

Nutrient was added to the KBE to supply an adequate source of nitrogen and phosphorus for optimum biological growth in the activated sludge reactors. To maintain a ratio of $BOD_5:N:P$ of 100:5:1, 6.3 grams of ammonium chloride (NH_4Cl) and 1.7 grams of diammonium hydrogen phosphate ($(NH_4)_2HPO_4$) were added to each barrel containing approximately 200 litres of KBE. Bioassay results carried out on samples containing different concentrations of nutrient are shown in Table 4. The results show that there was no significant change in toxicity due to the addition of nutrient up to 200% of the aforementioned concentration. The level of ammonia in the sample containing twice the required nutrient concentration was 19.9 mg NH_4-N/l . At a pH of 7.5, and temperature of $15^{\circ}C$, the concentration of the unionized ammonia has been reported to be toxic to rainbow trout (15), however, there was no apparent effect on the toxicity of the untreated KBE. As the sample had a MST of 265 minutes, the toxicity

could be attributed to the fact that other more toxic components were responsible for the mortality.

TABLE 4 Effect of Nutrient Addition on Toxicity

Nutrient Concentration*	MST	95% Confidence Limit
<u>%</u>	<u>(min)</u>	<u>(min)</u>
0	247	210-290
50	235	192-287
100	247	232-263
200	265	215-327

* The amount of NH_4Cl and $(\text{NH}_4)_2\text{HPO}_4$ added to maintain a BOD:N:P ratio of 100:5:1 was designated as 100% nutrient concentration.

Summary

The effect of storage conditions on the toxicity of KBE indicated that toxicity reduction was closely related to the sample pH. The rate of detoxification increased as the pH increased; a similar but more significant response was noted when neutralized KBE was aerated for 5 days. Storage temperature and nutrient addition had little effect on toxicity. Aeration rates seemed to have some effect on toxicity; however, the reduction in toxicity at increased aeration rates is small when compared to the toxicity change due to pH adjustment.

Results of this study emphasize that storage and handling of untreated KBE is an important factor to be considered when carrying out laboratory bench-scale studies. Neutralization and an extended storage period reduce the toxicity of KBE by chemical reaction, thus making it difficult to maintain a wastewater quality which is comparable to the original bleachery process effluent. Therefore, if bioassay data from the bench-scale study were used to predict results of pilot or full-scale operation, the results would be significantly different from field observations. This provides an explanation for the inconsistent bioassay results between bench-scale and pilot-scale studies reported in this project.

ACTIVATED SLUDGE TREATMENT OF KRAFT BLEACHERY EFFLUENT AT ELEVATED TEMPERATURES

The outfall temperature of bleached kraft mill effluents varies between 25 and 45°C depending on mill operating and local environmental conditions. At these temperatures, difficulties have been encountered in the treatment of this wastewater. Operational problems such as solid-liquid separation, dispersed growth and poor treatment efficiency have been reported in bench-scale activated sludge reactors (7).

The purpose of this portion of the study was to investigate the effect of temperature on treatment efficiency, to provide corrective methods for problems which might occur and to establish the maximum practicable operating temperature for an activated sludge system treating KBE. The experimental program was divided into two phases. In the first phase, three single-stage activated sludge reactors were operated in parallel at 22, 29 and 38°C to determine the temperature at which operational problems were likely to occur. In the second phase, four reactors were operated at 29, 32, 35 and 38°C to establish the optimum temperature at which an activated sludge system can be operated without creating serious operational problems.

Operation at 22, 29 and 38°C

Three bench-scale single-stage activated sludge reactors were set up in the laboratory. Submersible thermostatic heaters were used to control the temperature in aeration cells. The average operating conditions and experimental results of the 6-week operation are summarized in Table 5. As shown in the table, there was no discernable difference in treatment efficiency between the reactors operated at 22 and 29°C. Both reactors achieved a 90% BOD₅ reduction at an organic loading of 0.2 kg BOD₅/kg MLSS·day. No operational problems were encountered at these two temperatures throughout the 6-week operating period.

The reactor operated at 38°C achieved a BOD₅ reduction of 81%. Effluent from this reactor was high in suspended solids concentration caused by rising pin-point floc and a continuous loss of sludge over the weir of the clarifier. Analytical results revealed that nitrate and nitrite were not detectable in effluent samples indicating that the rising pin-point

floc was not due to denitrification in the clarifier.

TABLE 5 Average Operating Conditions and Experimental Results

A. Operating Conditions*

Reactor No.	1	2	3
Operating Temp. ($^{\circ}\text{C}$)	22	29	38
Organic Loading (kg BOD ₅ /kg MLSS·day)	0.2	0.2	0.3**
MLSS in the Aeration Cell (mg/l)	5600	5600	3900

B. Experimental Results

	<u>Influent</u>		<u>Effluent</u>	
pH	7.3	7.5	7.5	7.6
BOD ₅ (mg/l)***	108	11	11	20
Suspended Solids (mg/l)	57	51	51	114
TOC (mg/l)	322	238	217	257
TKN (mg/l)***	10.5	6.7	6.1	20
Total P (mg/l)***	2.3	1.8	2.0	2.7
SVI (mg/l)		127	94	149

* A feed rate of 40 ml/min provided an aeration cell and clarifier retention time of 2.1 and 3.5 hours, respectively: the overflow rate of the clarifier was 1.8 m³/m²·day (37.4 gpd/ft²) and the sludge return rate was 100% of the feed rate.

** The higher organic loading was attributed to the lower concentration of MLSS in the reactor caused by a continuous loss of sludge from the clarifier.

*** Non-filtered samples.

Efforts were made to maintain a MLSS concentration of 5,000 mg/l in all three reactors so that treatment efficiency could be compared at the same organic loading. This was not possible in the 38 $^{\circ}\text{C}$ reactor as the MLSS decreased from 4,900 to 2,900 mg/l over the 6-week operating period. Settling test data for sludge at 38 $^{\circ}\text{C}$ indicated that zone settling velocities were acceptable even though pin-point floc was present. Thus the occurrence of

pin-point flocs and sludge settleability were not related and should be recognized as two separate phenomena. In the study of temperature acclimation in activated sludge systems treating domestic waste, similar phenomenon was reported by Benedict and Carlson (16). Dispersed solids were observed in the effluent of the reactor operated at 32°C while the sludge flocs exhibited good settling characteristics as measured by a settling test.

Microscopic examination showed that the pin-point flocs had a structure similar to normal sludge particles. Bacterial cells and occasionally protozoa were observed. Protozoa such as Rotifers, Blepharisma and Opecularia were abundant in sludge flocs from the 22 and 29°C reactors, but were not present in the 38°C reactor. Only occasionally could stalked ciliates be observed in sludge flocs of the 38°C reactor. No filamentous microorganisms were found in any of the reactors throughout this study. Photomicrographs of sludge flocs from each reactor are shown in Fig. 4, 5, and 6.

Operation at 29, 32, 35 and 38°C

Results of the first phase of this study indicated that the maximum temperature at which an activated sludge system can be operated without producing a significantly high concentration of effluent suspended solids lay between 29 and 38°C. In order to determine this maximum temperature, four reactors were set up within this temperature range and operated in parallel for a 3-month period. Temperatures investigated were 29, 32, 35 and 38°C. Operating conditions and experimental results of this study are presented in Table 6.

Comparison of the operating conditions presented in Tables 5 and 6 shows that the four reactors were operated at a substantially higher organic loading than the three in the first phase. This increase was partially due to a decrease in the MLSS concentration and was compounded by the higher concentration of influent BOD₅. The MLSS concentration was purposely decreased to 3000 mg/l since a high quality effluent was obtained at the low F/M ratio of 0.2. It was intended to obtain a spectrum of effluent BOD₅ values at different loading conditions and temperatures in order to establish substrate removal rate constants.

As shown in Table 6, at an F/M ratio of 0.5, effluent BOD₅ concentrations were the same for all reactors. They were comparable with re-

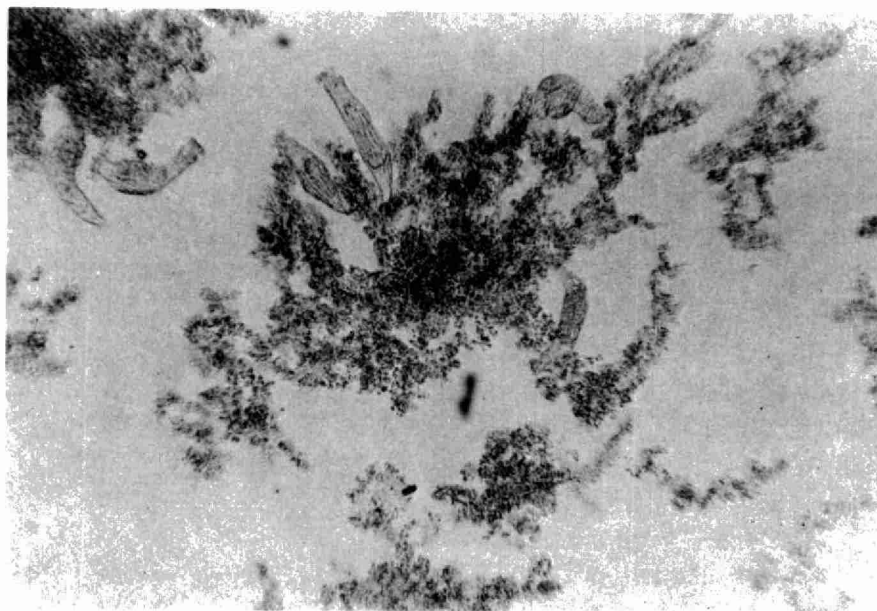


Fig. 4 TYPICAL SLUDGE FLOCS FROM THE 22°C REACTOR
(x 100)

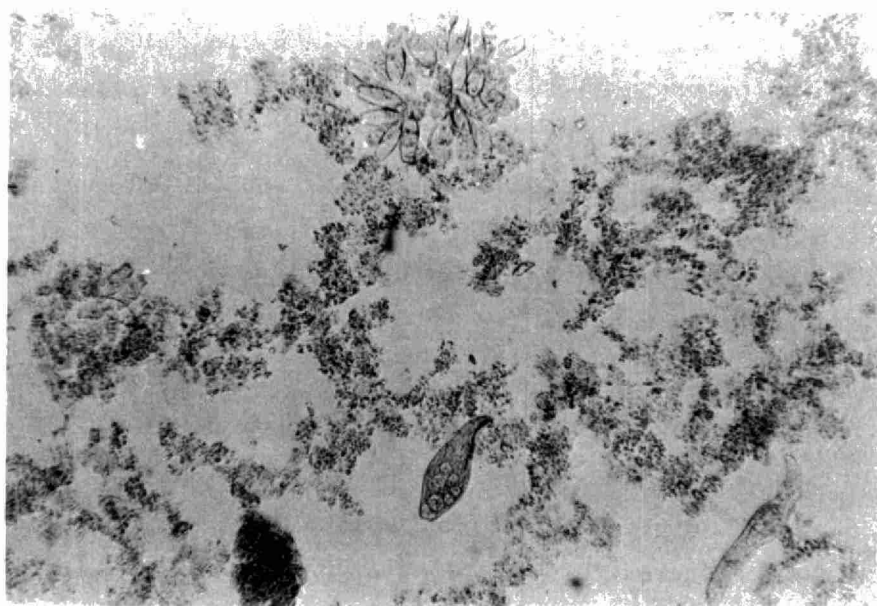


Fig. 5 TYPICAL SLUDGE FLOCS FROM THE 29°C REACTOR
(x 100)

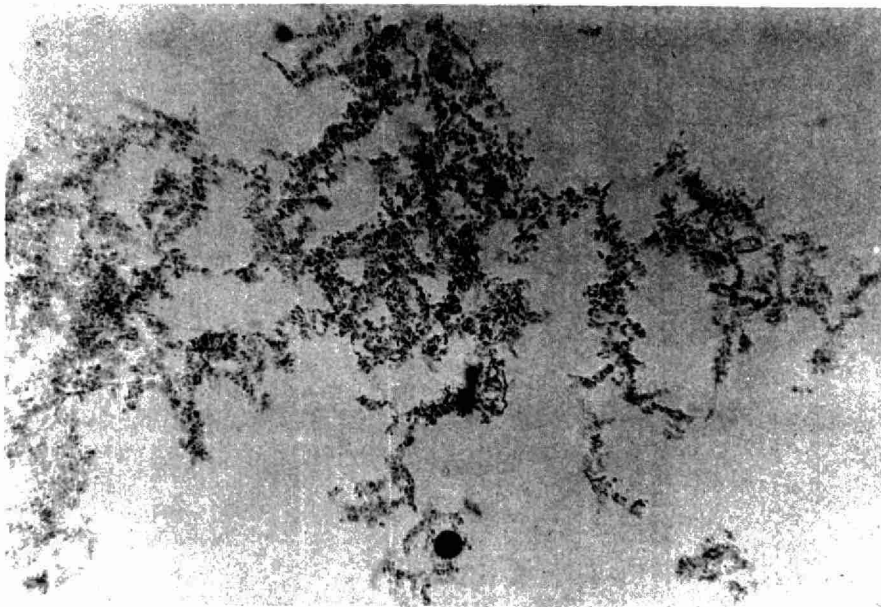


Fig. 6 TYPICAL SLUDGE FLOCS FROM THE 38°C REACTOR
(x 100)

sults obtained for the 22 and 29°C reactors operated at an F/M ratio of 0.2. Slightly lower effluent suspended solids were obtained at 29 and 32°C at the higher F/M ratio. The probability plot in Fig. 7 clearly shows that the increase in operating temperature from 32°C to 35°C resulted in a significant increase in effluent suspended solids. This suggested that the critical temperature at which a significant increase in effluent suspended solids could develop was between 32 and 35°C.

The higher concentration of effluent suspended solids at 35 and 38°C was attributed to the continuous rising of pin-point flocs in the clarifier. At the organic loading of 0.5 kg BOD₅/kgMLSS·day, no difficulty was encountered in maintaining the MLSS at 3,000 mg/l indicating that the sludge production rates were greater than the solids loss over the weir of the clarifier. Although the reactors operated at 35 and 38°C produced effluents with significantly higher suspended solids, sludge from these reactors exhibited slightly better settleability than that from the other two reactors. Zone settling analyses of MLSS were carried out periodically to investigate sludge settling characteristics. Preliminary results indicated that sludge from the 38°C reactor settled most rapidly.

TABLE 6 Average Operating Conditions and Experimental Results

A. Operating Conditions*

Reactor No.	1	2	3	4
Operating Temp. ($^{\circ}\text{C}$)	29	32	35	38
Organic Loading (kg BOD ₅ /kg MLSS·day)	0.5	0.5	0.5	0.5
MLSS in the Aeration Cell (mg/l)	3500	3100	3300	3200

B. Experimental Results

	Influent	Effluent			
pH	7.6	7.6	7.6	7.7	7.7
BOD ₅ (mg/l)	155	10	10	11	11
Suspended Solids (mg/l)	42	29	32	109(34)	81(38)
TOC (mg/l)	400	284	292	286	291
TKN (mg/l)	9.6	3.1	3.2	4.1	3.8
Total P (mg/l)	2.7	2.0	1.8	2.1	2.0
SVI (mg/l)		169	172	160	143

* A feed rate of 40 ml/min provided an aeration cell and clarifier retention time of 2.1 and 3.5 hours, respectively. The overflow rate of the clarifier was $1.8 \text{ m}^3/\text{m}^2\cdot\text{day}$ (37.4 gpd/ft^2) and the sludge return rate was 100% of the feed rate.

()Suspended solids values shown in brackets are average results from the three-week operation of reactors with temperature control units in the clarifier.

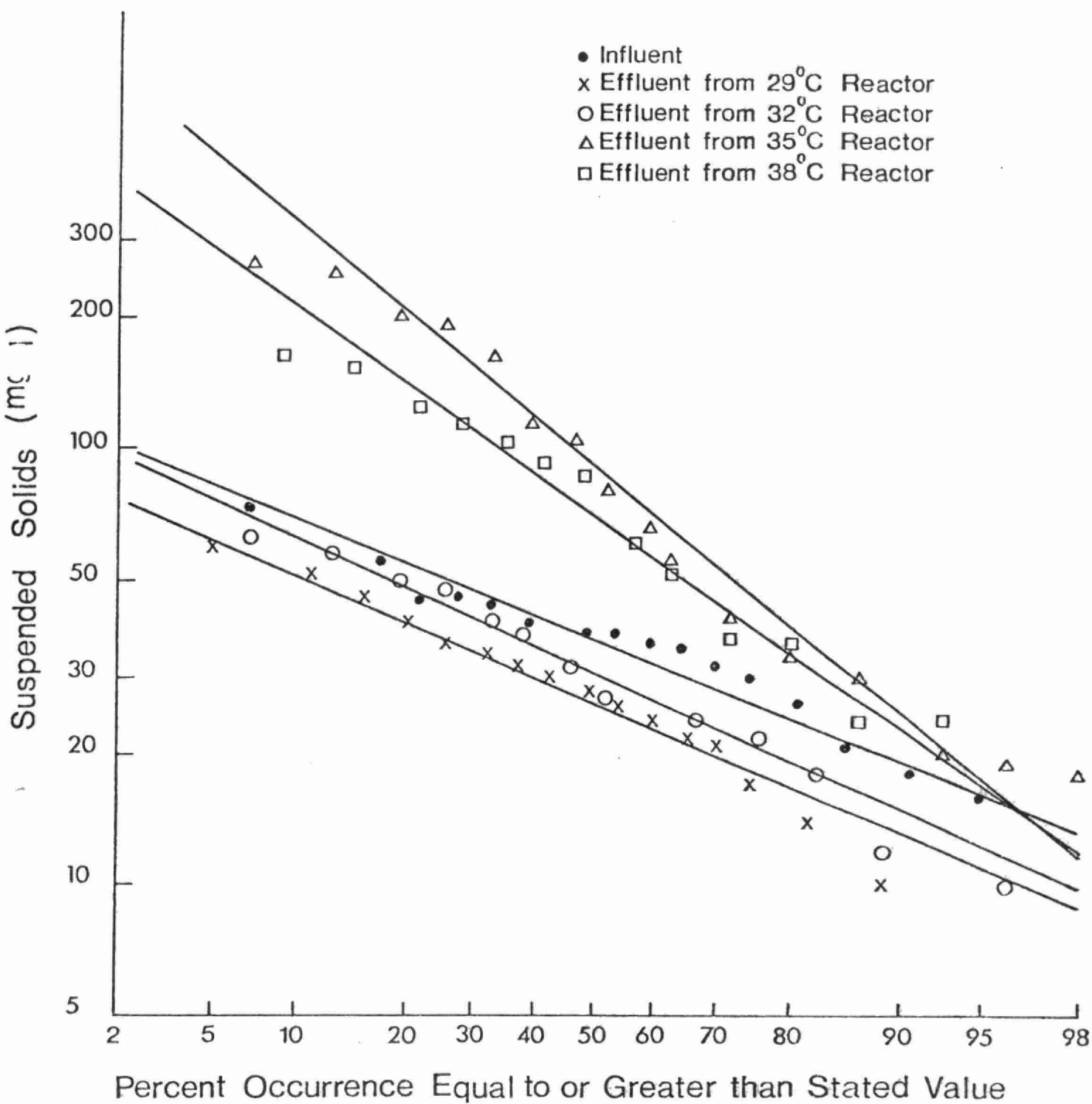


Fig.7 PROBABILITY DISTRIBUTION FOR SUSPENDED SOLIDS

As each treatment system was set up in a laboratory at room temperature with a thermostatic heater installed in the aeration cell, it was not possible to maintain a uniform temperature throughout the system. The liquid temperature difference between the aeration cell and clarifier was measured to be approximately 2, 3, 5 and 6°C, for treatment systems operated at 29, 32, 35 and 38°C respectively. As the surface of the clarifier was exposed to an ambient temperature of approximately 22°C and the incoming MLSS had a higher temperature, it was observed that the liquid temperature at the bottom of the 35 and 38°C clarifiers was approximately 1°C higher than that at the surface. The temperature differential in the 29 and 32°C clarifiers was almost negligible. It is possible that the temperature gradient in the clarifier produced convection currents causing heavier water close to the surface to move downward and the lighter water at the bottom to flow upward and push small sludge flocs to the surface.

To verify whether the problem of rising pin-point flocs was due to convection currents of thermal origin, thermostatic heaters were installed approximately 10 cm below the water surface in the clarifier of the 35 and 38°C reactors. This created an inverted temperature gradient with the temperature being 3°C higher at the surface than at the bottom of the clarifier. Within one day, the pin-point flocs disappeared as shown by the bracketed suspended solids values in Table 6. The effluent suspended solids of both reactors dropped to a level comparable with that of the 29 and 32°C reactors. When the heaters were removed, pin-point flocs began to rise again and effluent suspended solids increased to the previous level.

This was further confirmed by the operation of a reactor set up in an incubator having the temperature controlled at 38°C to eliminate the temperature gradient in the clarifier. Except for the concentration of MLSS which was 4,200 mg/l, operating conditions were similar to those of the 38°C reactor operated in the laboratory. No pin-point floc was observed in the clarifier during the one-month operation. Effluent suspended solids averaged 46 mg/l indicating a significant improvement in the performance of the clarifier at equalized temperature conditions.

Microscopic examination revealed that sludges from all reactors

consisted of large bacterial flocs which were similar in structure. The most significant difference in sludge characteristics between reactors was the protozoa population. For comparison, the relative number of protozoa observed in 1 ml of sludge sample taken from the different reactors are presented in Table 7. It should be emphasized that direct counting of protozoa was difficult because of the mobile characteristics of some species and the presence of large sludge flocs which tended to obscure the small species of protozoa. Results presented are for comparative purposes only.

TABLE 7 Relative Protozoa Populations

<u>Protozoa Species</u>	<u>Reactors</u>				<u>Remarks</u>
	<u>29⁰C</u>	<u>32⁰C</u>	<u>35⁰C</u>	<u>38⁰C</u>	
Rotifer	PPPP	PPPP	PP	A	P - Present
Euplotes	PPPP	PP	A	A	A - Absent
Opecularia	PPP	PP	PP	P	
Blepharisma	PP	P	A	A	
Lionotus	PP	A	A	A	
Nematode	P	P	A	A	
Podophrya	P	A	A	A	
Amoeba	A	A	PP	PP	
Flagellates	A	A	PPPP	PPPP	
Other unidentified ciliates	PP	P	A	A	

As shown in the table, protozoa populations decreased as operating temperature increased. Sludges taken from reactors operated at lower temperatures have significantly more protozoa both in number and species. While Rotifers and Euplotes were present in large numbers in the 29 and 32⁰C reactors, they disappeared in the reactors operated at higher temperatures. Flagellates were most numerous in the 38⁰C reactor. Photomicrographs of sludge flocs from each reactor are presented in Fig. 8, 9, 10 and 11. Although some filamentous microorganisms were observed in sludge flocs of the 38⁰C reactor, they were not numerous enough to induce poor sludge settleability as indicated by the results of zone settling tests.



Fig. 8 TYPICAL SLUDGE FLOCS FROM THE 29°C REACTOR
(x 100)

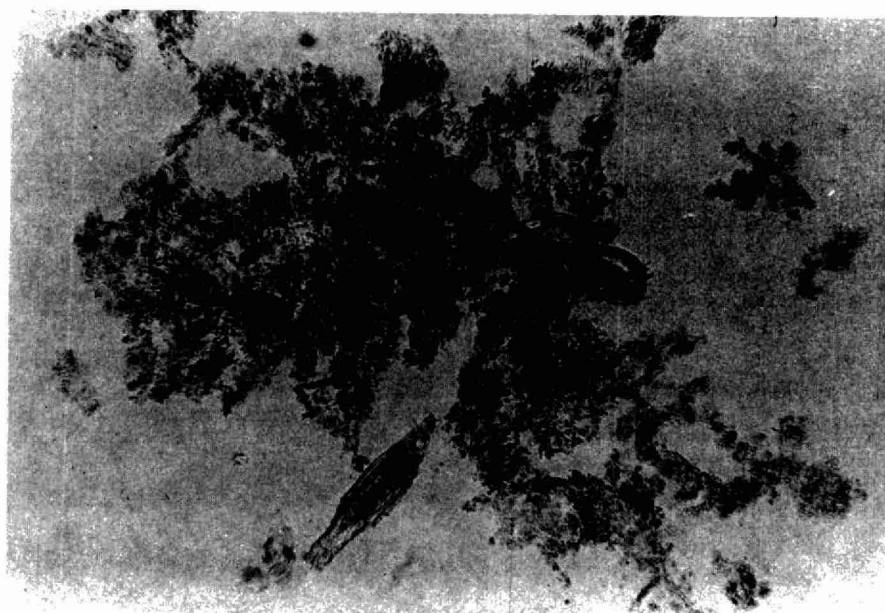


Fig. 9 TYPICAL SLUDGE FLOCS FROM THE 32°C REACTOR
(x 100)

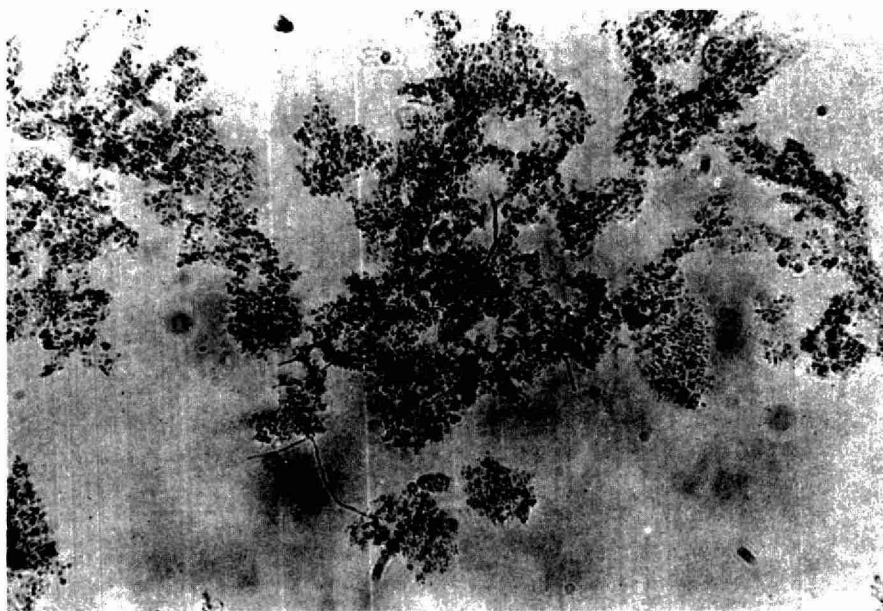


Fig. 10 TYPICAL SLUDGE FLOCS FROM THE 35°C REACTOR
(x 100)

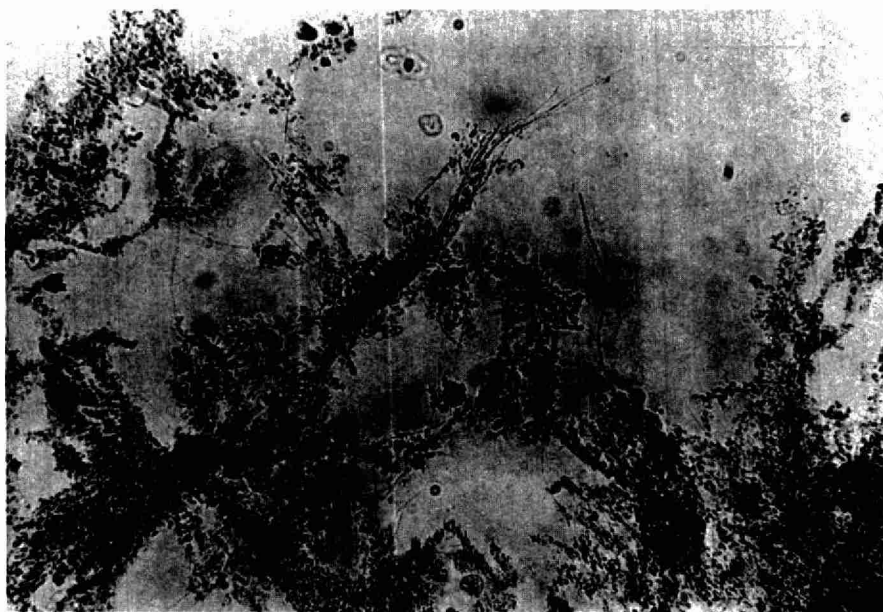


Fig. 11 TYPICAL SLUDGE FLOCS FROM THE 38°C REACTOR
(x 100)

Activated sludge treatment of bleached kraft mill effluent, carried out by B.C. Research (7) showed that temperature significantly affects the settling characteristics of sludge flocs. Operation of reactors at 36 and 40°C resulted in operational problems including high concentrations of effluent suspended solids. Substantial improvement in effluent quality was attained in a unit operated at 30°C. It was suggested that the poor settling characteristics of sludges at higher temperatures might be related to the presence of a dominant bacterial species which was not capable of excreting the polysaccharide material considered to be responsible for sludge flocculation. Another explanation was that, assuming the same bacterial species were present in all reactors, metabolism could be affected by higher temperatures so that the cementing polysaccharide material was not produced. In addition, for this study, the 5-6°C temperature difference between the aeration cell and the clarifier in the 35 and 38°C systems continuously subjected the microbial population to a cyclic change in temperature. This temperature shock combined with the fact that reactors were operated beyond the optimum growth temperature for mesophilic bacteria could detrimentally affect the flocculating mechanism of microorganisms.

The equilization of temperature throughout the treatment system and also the creation of an inverted temperature gradient in the clarifier were successful in eliminating the rising pin-point floc. This suggests that the temperature gradient - a physical factor - could be more significant than the above mentioned biological factors, in affecting the performance of the activated sludge systems.

Bioassay Results

Bioassay results obtained during the operation of reactors at 22, 29 and 38°C indicated that the median MST was 13.3 hours for untreated KBE while 100% survival was observed over 96 hours for effluents from the 22 and 29°C reactors. Although effluent from the reactor operated at 38°C had an MST of greater than 96 hours, some mortality was observed during the test. In the second phase of this study the median MST of the influent KBE was 6.2 hours. For effluents, a median MST of greater than 96 hours was also achieved from all reactors. No significant difference in toxicity was observed among effluents from the four reactors. Although bioassays

were not carried out according to procedures specified in the Pulp and Paper Effluent Regulations (5), it was anticipated that regulatory standards could easily be met had these tests been performed on effluent samples.

A comparison of bench and pilot-scale results revealed that even at a higher organic loading, bench-scale reactors produced significantly better effluent quality. Substantially greater BOD₅ reduction and toxicity removal were achieved. This was partially attributed to the fact that the pilot-scale reactors were frequently subjected to shock loadings such as a sudden change in the concentration or composition of wastewater, while the bench-scale reactors were operated for extended periods with a homogeneous supply of KBE. This condition, combined with the fact that there was a reduction of toxicity during storage, explains why effluents from the bench-scale unit were much less toxic than effluents from the on-line pilot-scale system treating KBE.

CONCLUSIONS

Based on results of the study, the following conclusions can be made:

1. This study points out that for kraft bleachery effluent the successful generation of process design data from bench-scale studies is dependent on recognizing the importance of changing waste characteristics due to length of storage, pH and aeration.
2. Chemical reactions were considered to be more important than biological oxidation in reducing the toxicity of kraft bleachery effluent; as a result aerated stabilization basins having much longer aeration periods are generally more effective in detoxification than activated sludge systems.
3. Operation of activated sludge systems at 35°C or higher resulted in deterioration of effluent quality with a substantial increase in concentration of effluent suspended solids. Significant improvement in effluent quality was attained in reactors operated at lower temperatures.
4. The deterioration of effluent quality was related to a continuous rising of pin-point floc which was considered to be partially due to a temperature gradient in the clarifier. Elimination or inversion of the temperature gradient was successful in controlling the rising of pin-point floc.
5. The critical temperature at which a substantial increase in effluent suspended solids could develop was between 32 and 35°C. To obtain improved effluent quality, an operating temperature of less than 35°C was recommended for an activated sludge system treating kraft bleachery effluent.

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THE CLOSED-CYCLE BLEACHED KRAFT PULP MILL

The three major problems facing the world's pulp and paper industry are: fibre supply, energy supply and environmental protection. All three are helped by completely re-using all process streams, and avoiding primary, secondary and tertiary effluent treatment.

The first closed-cycle bleached kraft pulp mill will have normal, continuous kraft pulping, chemical recovery, bleaching by the D/CEDED sequence and pulp drying. The process involves decreasing water usage by complete countercurrent washing from the pulp drier, through the bleach plant, the screening system and the unbleached pulp washers into the evaporator.

The capital and operating costs for the closed-cycle mill are much less than those incorporating primary and secondary treatment, inadequate as these are. No external treatment will be required to remove BOD, COD, suspended solids, colour or toxicity because these are destroyed within the mill. Only clean, clear water will be discharged.

The Salt Recovery Process co-invented at the University of Toronto with Dr. Douglas Reeve, has been developed through the pilot plant stage to full scale commercial use by Erco Envirotech Ltd., a joint venture of Erco Industries Ltd. of Canada and Envirotech Corporation of U.S.A.

by

DR. W. HOWARD RAPSON

Professor of Chemical Engineering
University of Toronto



Dr. Rapson received his B.A.Sc., in Chemical Engineering from the University of Toronto in 1934, his M.A.Sc., in 1935 and his Ph.D., in 1941.

After twelve years in pioneering research with Canadian International Paper Company, he returned to the University of Toronto as Professor of Chemical Engineering and became a consultant to the pulp and paper industry.

The Closed-Cycle Bleached Kraft Pulp Mill

W. Howard Rapson
Professor of Chemical Engineering
University of Toronto

There are three main problems facing the world's pulp and paper industry:

- 1) fibre supply;
- 2) energy supply; and
- 3) the environment.

Fast growing trees, such as those being developed on plantations in Brazil, are the key to the first, along with increased yield of pulp from wood. Better utilization of part of the wood for producing the energy required for pulping is the key to the second. Complete recycle and combustion of all contaminating effluent streams is the key to the third. This also greatly helps the first two, by increasing yield, by decreasing energy requirement for pulping and bleaching and by avoiding the high energy consumption of the relatively ineffective effluent treatment processes now used.

External Effluent Treatment

Kraft pulp mills normally now have three major water polluting effluents: from the wood room; from black liquor left in the washed unbleached pulp, which usually leaves the screen room after thickening on the unbleached stock decker, and the bleach plant effluent, which contains the major pollution load.

Pollution can only be eliminated by a series of increasingly costly effluent

treatments, or by recycling all polluted water within the mill, which is much cheaper.

Primary effluent treatment settles out a large part of the suspended solids. Secondary treatment biologically oxidizes part of the dissolved and suspended solids, but still leaves 5 to 15% in the effluent. Furthermore, this effluent still contains all the colour, a large part of the toxicity, and often unacceptably high suspended solids. It also contributes nutrients, nitrogen and phosphorus, which must be added to the secondary treatment to allow the micro-organisms to grow. None of the salt is removed. Each softwood bleached kraft pulp mill now puts about 240 lb sodium chloride per ton of pulp into the receiving stream.

To meet the ultimate zero discharge requirement in the U.S.A., Arthur D. Little has costed out a proposal to evaporate all the secondary effluent, about 40,000 gallons per ton of pulp, and crystallize out the salts and bury them! The cost was \$72 per ton of pulp in 1972 dollars! No mill would even consider such a process! The energy required would create more pollution than the process would eliminate! There must be a better way!

Nearly ten years ago I conceived the possibility that water pollution could be eliminated from bleached kraft pulp mills by integrating several older processes with two new ones, with no substantial change in the kraft pulping and bleaching process (1,2). This point is very important. Attempts are being made worldwide, to develop processes for pulping with chemicals not containing sulphur to avoid the smell produced by kraft mills, and to develop bleaching processes avoiding chlorine-containing chemicals, in order to permit putting the bleach plant effluent.

into the pulping chemical recovery system without producing sodium chloride, for which there is no purge in our present kraft mills.

Yet none of the non-sulphur pulping processes so far investigated in the laboratory has produced a pulp on a mill scale which is as strong or as useful for papermaking as kraft; nor has any of the non-chlorine bleaching processes produced a bleached kraft pulp as strong, as white, and as stable as that made with our chlorine dioxide bleaching sequence.

There is always a possibility that a competitive non-sulphur pulping process will be developed, and that a competitive non-chlorine bleaching process will be discovered; however, I believe that we will continue to use the kraft pulping process and solve the smell problem, and that we will continue to use chlorine dioxide for bleaching and solve the water pollution problem. The probability of presently proposed alternatives becoming widely accepted is relatively small.

Therefore, while I have investigated most of the bleaching alternatives in the laboratory, I have concentrated my research and development programme

- on
- 1) improving pulp properties,
 - 2) decreasing the cost of producing the bleached pulp, and
 - 3) eliminating water pollution by bleached kraft pulp mills, while continuing to use chlorine dioxide for bleaching.

I intend to summarize the results to date.

The World's First Closed-Cycle Bleached Kraft Pulp Mill

The world's first bleached kraft pulp mill essentially free of water pollution will make 700 tons per day of 90 brightness softwood and hardwood kraft pulp. It will recycle all contaminated process streams, eliminating virtually all polluting liquid effluents. There will be practically no BOD, no COD, no suspended solids, no colour, no toxicity, no heavy metal cations, and no nutrients entering the receiving stream. There will be no primary nor secondary effluent treatment. In fact, the water leaving the plant will be purer than the water coming in, since the only process stream leaving will be distilled water!

Low temperature heat will leave the mill in uncontaminated, thermally enriched cooling water. If this cannot be accepted in some other locations, the heat can be transferred to the atmosphere in an evaporative cooler, and then no liquid water will leave the mill!

The mill's water and energy consumption will be drastically decreased. Pulp yield, strength and brightness stability will be improved. The capital and operating costs of the closed-cycle mill are substantially lower than those normally incurred with primary and secondary external effluent treatment.

How is all this accomplished?

To make any pulp mill non-water-polluting, the wood room must operate completely on recycled water. The accumulated suspended solids will be filtered or centrifuged out and burned. A closed pressurized screening system will operate between the unbleached washers and the decker, using recycled decker filtrate.

The screen rejects will be filtered and burned.

Since unbleached pulp will be washed entirely by continuous diffusion, there will be no air-water interface to produce foam.

In the bleach plant the amount of water used to wash the pulp in the five stages (D/C EDED)^x is sharply decreased by counter-current washing and recycling chlorination filtrate to dilute the unbleached pulp entering the first stage.

The bleach plant effluent and evaporator condensates are used to wash the unbleached pulp, thus eliminating the unbleached pulp wash water. The spent bleaching chemicals and the organic matter dissolved during bleaching are carried into the evaporators and into the furnace, where all organic matter is burned and the inorganic smelt is dissolved, settled, and filtered to remove the dregs, and causticized to form white liquor for re-use in pulping (1, 2, 3, 4, 5).

There are several consequences of this procedure. First, all chlorine in the bleaching chemicals ends up as sodium chloride in the chemical recovery system, and must be removed. Since there is no planned purge for salt in the normal chemical recovery system, Dr. Douglas Reeve and I invented the salt recovery process, which has been developed through the pilot plant stage and brought to commercial installation by Erco Envirotech Limited (4, 5, 6, 7).

Secondly, all stages of bleaching will be hot, including the first or chlorination stage, as well as all parts of the pulping process. Chlorine dioxide will be substituted for seventy percent of the available chlorine normally used in the first stage. This has many great advantages.

^x D = chlorine dioxide, C = chlorine, E = caustic extraction, D/C = mixture

1. The pulp is stronger.
2. The pulp is more stable toward yellowing with age.
3. The pulp is cleaner because the shives are more completely pulped.
4. The yield of pulp is increased by about 1% because the chlorine dioxide does not degrade and dissolve the carbohydrates as much as chlorine does. (The yield is also higher because there is no loss of fiber, since there are nine filtrations of the same liquor, since no process stream leaves the mill. This countercurrent washing can save 1-3% of pulp, depending on how the mill is normally operated.)
5. High temperature can be used ($60-70^{\circ}\text{C}$) in the chlorination stage without decreasing the strength of the pulp.
6. The amount of sodium hydroxide required for bleaching is decreased to half of that required with all chlorine, since ClO_2 has five oxidizing equivalents per mole for each chlorine atom, while chlorine has only one equivalent for each chlorine atom.
7. The amount of sodium chloride produced per ton of pulp is cut in half, substantially decreasing the chloride load on the recovery furnace, and decreasing the amount of salt which must be removed by the salt recovery process.
8. Seventy percent replacement of chlorine by chlorine dioxide in the first stage decreases the colour of the bleach plant effluent about 50%, and the COD and BOD by 15-20%, and eliminates the toxicity towards fish normally found in the chlorination effluent. This is only an advantage

prior to recycling all the process water in the mill.

9. The cost of chemicals in an effluent-free mill is lowered by substituting 70% chlorine dioxide for chlorine in the chlorination stage, mainly because the amount of sodium hydroxide required to produce sodium chloride from all the chlorine atoms entering the bleach plant is decreased fifty percent.

Although it was considered to be impossible by most people when I first proposed it in 1967 (1), complete countercurrent washing from the last stage to the first stage with the same water, using the filtrate from each stage as shower water on the previous stage washer, is widely accepted and practised today (8, 9). Furthermore, the chlorination filtrate is now being used to dilute the pulp coming from the unbleached storage chest and carry it into the chlorination tower, as well as for dilution of the pulp leaving the first stage and transporting it to the washer vat.

Recycling Chlorination Stage Filtrate

This recycling of the chlorination stage effluent raises the temperature of the chlorination stage for two reasons. First, the heat of the reaction of the chlorine dioxide and chlorine with the lignin is not removed in the wash water, but accumulates, and since the same wash water is used for the chlorination after being used in the later stages, which are all hot, the chlorination stage temperature will be nearly as high as that of the later stages.

Recycling the chlorination filtrate increases the hydrogen ion concentration in the chlorination stage, since the hydrochloric acid produced by reaction of chlorine

and chlorine dioxide with the pulp is recycled and accumulates. This also increases the chloride concentration in the chlorination stage. The combination of higher acidity and higher chloride concentration increases the corrosiveness of the chlorination stage liquor. Therefore all metal equipment in the chlorination stage and the washer must be resistant to these more corrosive liquors.

The acidity of the chlorination filtrate is substantially decreased, that is the pH is higher, when 70% chlorine dioxide is used, because the hydrogen chloride produced is cut in half.

Heat Saving

One of the major consequences of sharply decreasing the water requirements by countercurrent washing is a very substantial saving in heat. Since the filtrate from the last stage will be hot, and the filtrate flows countercurrently through the system, all bleaching stages will remain hot, except for the cold water used to dissolve chlorine dioxide to carry it into the bleach plant. Therefore the last four stages will be at 70°C, and the first stage probably at 60°C. In fact, there will be no cold part of the mill from the time the wood leaves the digester until the pulp leaves the drying machine, or is sent to the paper machine. The saving in steam amounts to about 3000 pounds per ton of pulp. Part of this steam is used to evaporate the white liquor, but there is a substantial net saving in heat.

Since half the heat produced from combustion of dissolved organic matter in a bleached kraft pulp mill normally is in the wash water leaving the mill, the problem in the effluent-free pulp mill will be to remove the heat. There are very

few options. Either the heat is transferred to clean water and discharged without contamination by process streams; or the heat is transferred to the atmosphere, either by evaporation of water in a cooling tower, or by using very expensive water-to-air heat exchangers. In the world's first non-water-polluting bleach kraft pulp mill the option chosen is to transfer the heat to clean water by using all indirect heat exchangers on the evaporators and on the condensates from the digester and from blow heat recovery.

Purging Impurities

In an effluent-free pulp mill, all impurities, no matter how small their concentration, will accumulate unless a purge for each of them is built into the system. First and foremost, sodium chloride will accumulate when the bleach plant effluent is introduced into the chemical recovery system. Our salt recovery process removes the sodium chloride at exactly the rate at which it is introduced into the mill with the wood, with the make-up process water, with the make-up chemicals, or through the recovery of bleach plant effluent.

Since the wood comes in containing more potassium ions than sodium ions, potassium will accumulate in an effluent-free mill, and either potassium compounds must be used for pulping, or potassium must be purged from the system. We had hoped that pulping with potassium would have some benefits, but we found no advantage using potassium hydroxide and potassium sulphide for cooking, but no disadvantage either. Potassium salts may have an advantage or a disadvantage in the recovery furnace, depending on how it is operated. However, we have developed a relatively simple system for removing potassium salts from the white liquor, if this should

become necessary in the effluent-free mill.

Heavy metal cations will be purged in the same manner as they are now, mainly in the dregs from settling the green liquor. There will be less heavy metal ions per ton of pulp introduced in the effluent-free mill, because the quantity of wood used will be less due to the higher yield, and the make-up chemicals and make-up water requirements are drastically decreased.

Silica and phosphorus might accumulate, but we expect these to be kept to their present levels by removal with the grits from the lime kiln in the same manner as they are at present. If it should become necessary due to unusually high introduction of silica in the raw materials, for example when pulping bamboo, we have other processes available for removing the silica. We do not think these will be necessary.

Chloride in the Recovery System

A higher concentration of sodium chloride in the recovery system is resisted by many pulp-mill operators due to two wide-spread, but unsubstantiated beliefs; first that chlorides enhance corrosion in the unbleached washers, evaporators and the boiler tubes, which it does not, and that sodium chloride causes explosions in the recovery furnace, which it does not.

The fact is that many mills in the world have been operating for more than 25 years with higher concentration of sodium chloride in the liquor system than we will have in the effluent-free mill with our salt recovery process. More than a dozen mills have more than 25 grams per litre of sodium chloride in their white

liquor, due mainly to floating logs in seawater for transport to the mill. The highest published concentration was 100 g/l at Powell River mill of MacMillan Bloedel Ltd. in British Columbia, Canada (10). That mill purges the chloride by using white liquor for caustic extraction and discharging the caustic extraction filtrate into the ocean. The amount of white liquor bled out of the system to purge sodium chloride in this manner is controlled to keep the sodium chloride concentration in the white liquor between 60-70 g/l. This has been done in that mill for more than 4 years.

Therefore there is a lot of experience on which to obtain the facts on the effect of sodium chloride in the white liquor.

In alkaline solution above pH 10, the presence of chlorides has no significant effect on corrosion. Therefore in the digester, in the evaporators, and in the green and white liquor systems there is no corrosion attributable to chlorides. This is the conclusion from studies in many mills carried out by a TAPPI committee.

The cause of every kraft pulp mill furnace explosion is studied very carefully by a special investigating team. In no case has the explosion been attributed to the presence of chloride in the smelt. It is a fact that smelt is increased in sensitivity to smelt-water explosion as the concentration of sodium chloride increases. However, the smelt is already very sensitive to smelt-water explosion because it is sensitized by sodium sulphide a major normal component. Since it is already extremely sensitive, water must not be allowed to get into the smelt, or if it does rapid shut-down procedures must be introduced immediately. Any additional sensitivity towards explosion due to the chloride present has no significant effect, because

the smelt is already very highly sensitive. In actual fact, the statistical record shows a lower frequency of explosion in those mills with high chloride content than those with low chloride content!

Increased chloride ion concentration does have a substantial effect on the corrositivity of acid solutions on steels and stainless steels. However, only in the chlorination stage is the acidity high enough to permit the presence of chloride to have a substantial effect. Therefore more resistant metals must be used in the chlorination stage.

The Salt Recovery Process

The sodium chloride introduced into the chemical recovery system by recovery of the bleach plant effluent, along with sodium chloride arising from other sources, such as wood, water or chemicals, is removed at exactly the rate at which it is being introduced. For bleaching softwood with 70% replacement of chlorine by chlorine dioxide in the chlorination stage in a D/C EDED sequence, the salt introduced would be about 120 lb per ton of pulp, but with 100% chlorine in the chlorination it would be about double that, 240 lb per ton.

Salt Removal from Precipitator Dust

As the chloride concentration in the white liquor and black liquor increases, the particulate matter in the flue gas which is removed by the electrostatic precipitator contains proportionally more sodium chloride. Its concentration may reach 30 to 40% the remainder being mostly sodium sulphate. In my first paper on the effluent-free mill (1), I suggested that the salt might be removed by leaching the precipitator dust

with enough water to dissolve most of the salt, but insufficient water to dissolve the sodium sulphate. This increases the concentration of salt in the water solution by 18 times, and if it is thrown away, only about 1 lb of sodium sulphate is wasted for 5 lb of salt. This process has been developed to commercial scale by MacMillan Bloedel Ltd. in Canada (11).

Unfortunately this process has several disadvantages. First, the maximum amount of sodium chloride removable is about 50 lb/ton of pulp, and even this can only be done by greatly increasing the sodium chloride content of all the liquors, and the smelt. Secondly, there must be some place to dispose of the concentrated salt solution, and generally this is only possible on the sea coast. Thirdly, the loss of 1/6 lb of sodium sulphate with each lb of salt is wasteful.

Salt Removal by White Liquor Evaporation

When either green liquor or white liquor is increased in concentration, the solubility of sodium chloride decreases, and sodium chloride crystallizes out. Among many options we have patented (12, 13, 14, 15, 16), we have chosen two stage evaporation of white liquor for the first water-pollution-free bleached kraft pulp mill (17). In the triple effect first stage of evaporation sodium carbonate plus sodium sulphate in the form of Burkeite, a double salt containing 1 mole of sodium carbonate per 2 moles of sodium sulphate, are crystallized out, but no sodium chloride. About 80% of the total evaporation occurs in the first stage. The crystals are filtered off, and recycled, partly to the green liquor to recausticize the carbonate and partly to the black liquor ahead of the furnace to reduce the sulphate to sulphide.

In the second stage single-effect crystallizer-evaporator, sodium chloride is precipitated along with the small amount of remaining sodium carbonate and sodium sulphate. The concentrated white liquor containing less than 25 g/l sodium chloride is diluted and sent to the digester for pulping. The sodium chloride precipitated is leached with water to dissolve the sodium carbonate and sodium sulphate which are returned to the first stage of evaporation. The remaining purified salt is available for electrolysis to produce sodium hydroxide and chlorine and/or to produce sodium chlorate for the manufacture of chlorine dioxide. The recovered sodium chloride may be used for any other purpose, sold, or put into the ocean.

Stoichiometric Balance

In a mill in which water and all chemicals are recycled, if nothing escapes, the sodium chloride removed must balance stoichiometrically with the sodium hydroxide, chlorine and chlorine dioxide used in the process. If it does not, the chemical inventory will increase or decrease. It also follows that the amount of sodium chloride removed is exactly that required to produce the sodium hydroxide, chlorine, hydrochloric acid and sodium chlorate used to produce the bleaching chemicals. Theoretically, in an entirely closed mill the chemical inventory should be constant, only electricity being consumed. In practice, there will be an increase in sodium chloride introduced with the wood and some loss of solid particles to the atmosphere, although this must be minimized.

Chlorine Dioxide Manufacture

When 70% of the chlorine in chlorination is replaced by chlorine dioxide, the chlorine dioxide requirement for softwood using the D/C EDED sequence is about 64 lb per ton of pulp, or 24 tons per day for a 750 ton per day mill. This will require a large, effluent-free chlorine dioxide plant.

Our Erco R3 chlorine dioxide process (which Hooker calls the S. V. P. process) uses a combined crystallizer, generator and evaporator in a single vessel (18), operated at low acidity (19) (about 4 N H_2SO_4) and produces only ClO_2 , Cl_2 and anhydrous Na_2SO_4 . At present, about 25 such plants are operating or are on order in Canada, United States, Soviet Union, Japan, New Zealand, Brazil and Finland.

However, these very efficient, low cost plants produce about 2.3 lb Na_2SO_4 per lb ClO_2 . An effluent-free kraft mill will require very little sodium sulphate for make-up. Erco Industries Limited has patents on the R4 (20, 21) and R5 (22) processes, both of which substitute HCl for H_2SO_4 , and produce NaCl instead of Na_2SO_4 . Both these processes use an R3 generator, and also operate at high efficiency, and are available wherever they are needed.

Cost Saving

The capital cost of building a new bleached kraft mill, completely eliminating water pollution (2, 6) is only about 5% more than building the same mill with no effluent treatment. This must be compared with 15% additional capital required to provide primary and secondary treatment, sludge disposal and colour removal.

However, the operating cost (including the cost of capital) of an effluent-free mill, taking into account the increased yield of pulp on wood, the energy saving, and the lower water cost, is only about 1% more than that of present mills without effluent treatment. The operating cost of a new mill with primary treatment, secondary treatment, sludge removal and colour removal, is about 10% higher than that of a mill without effluent treatment.

Yet about ten percent of the pollutants still remain in the effluent after treatment. To decrease the pollutant load further by external treatment would increase both capital and operating cost exponentially. Therefore it is very much cheaper to eliminate water pollution by internal recycle of process water.

The Future

I firmly believe that the kraft process will continue to be used and new kraft mills will continue to be built. Both air and water pollution will be eliminated. Chlorine dioxide will continue to be the main bleaching agent, in a dynamic bleaching process.

All kraft pulp mills will eventually become effluent-free, and process water will be completely recycled at substantial saving in capital and operating cost compared with effluent treatment.

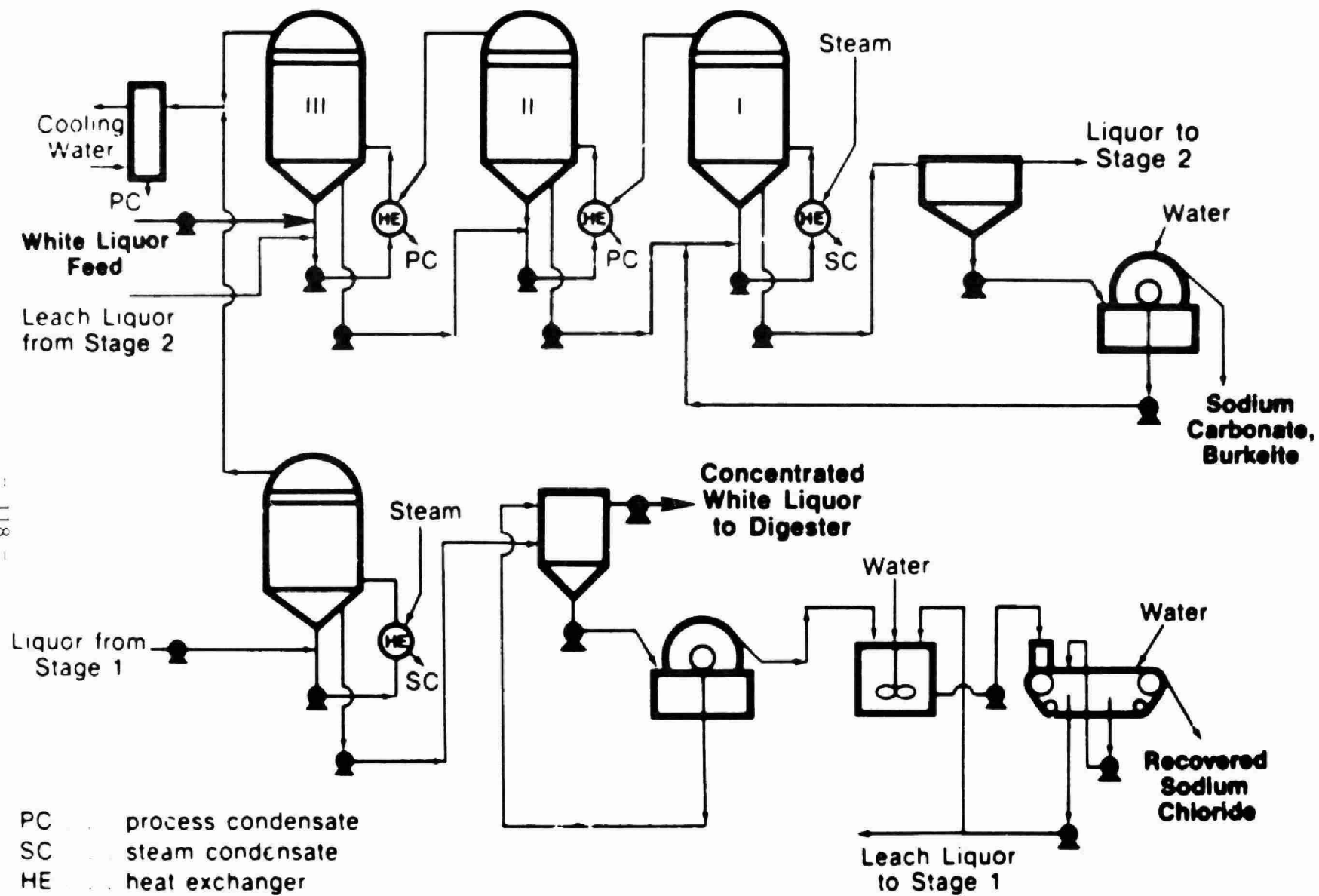
The already high quality of bleached kraft pulp will be improved, and the yield will be increased.

I expect the first such closed-cycle bleached kraft pulp mill to begin operation in 1976.

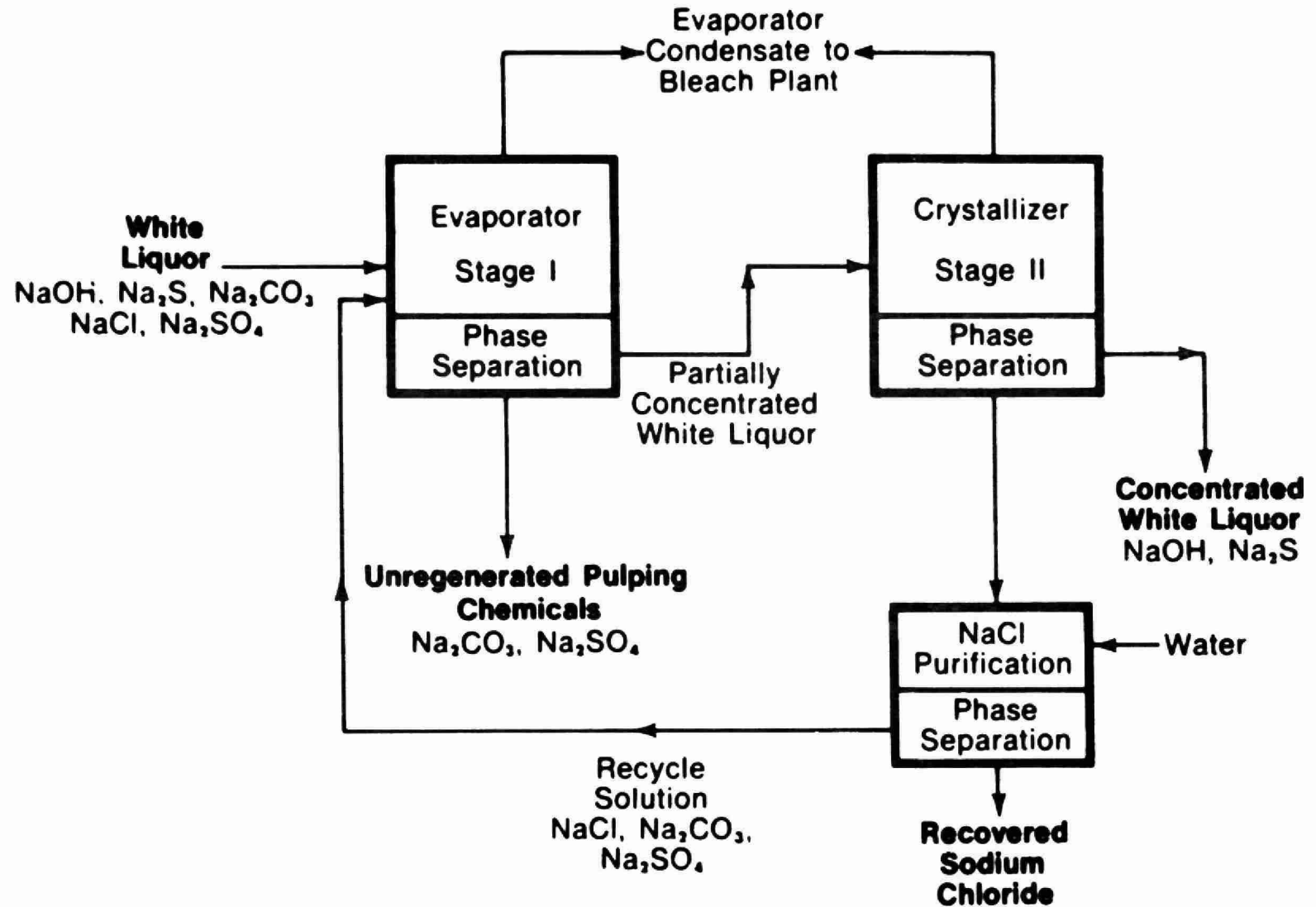
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THE SALT RECOVERY PROCESS



THE EFFLUENT-FREE MILL

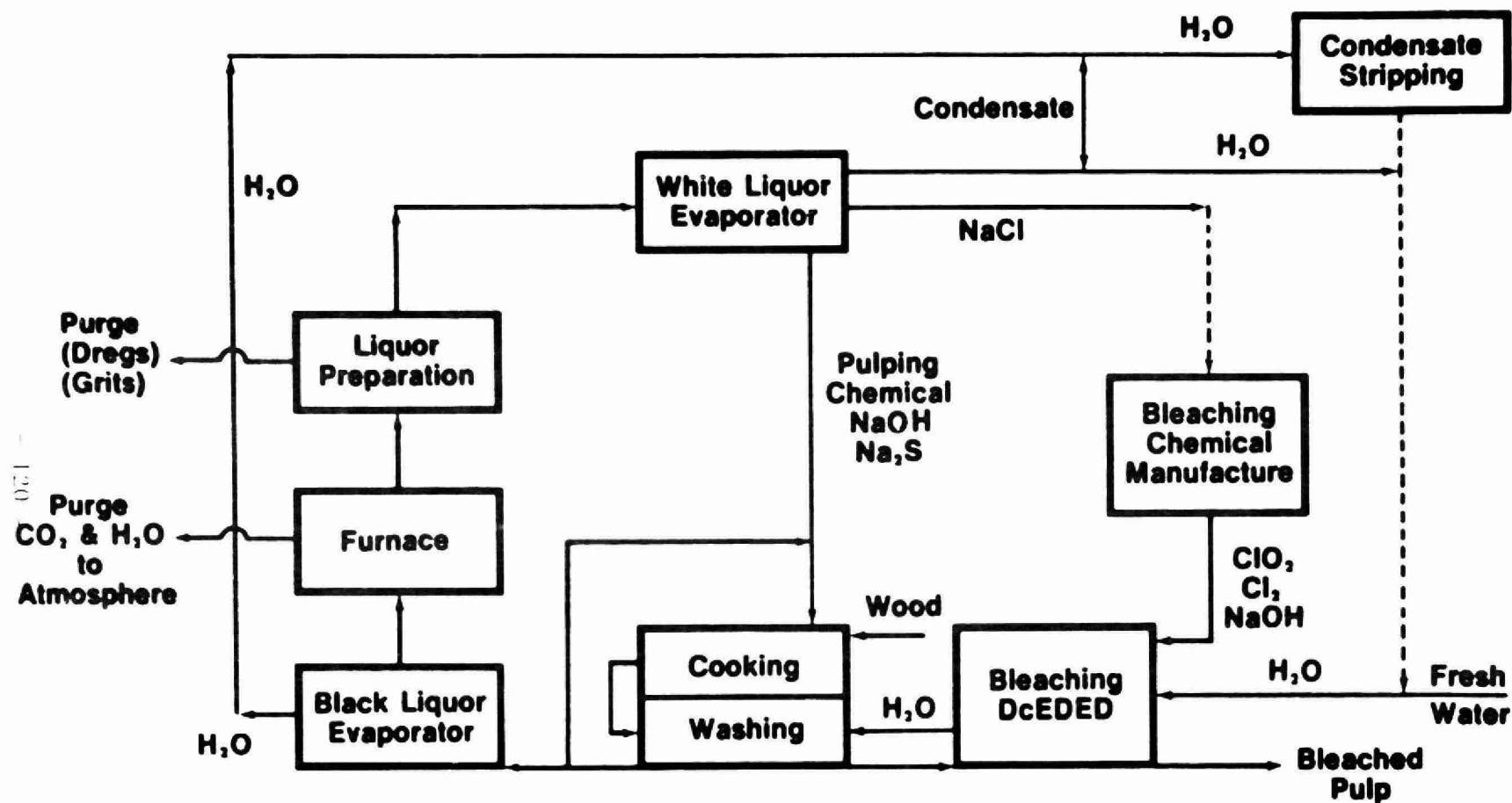


FIGURE 1

CUPOLA EMISSION CONTROLS & PROBLEMS

This paper presents a review of the major sources of air pollution in a ferrous foundry and some of the problems in collecting the emissions, and disposing of the collected material. The production areas covered will be the melting operation, cupola and its auxiliaries; shakeout and sand return system; and the general exhaust ventilation system for the working areas.

The investigation of types and designs of cupola emission control systems, their selection in relation to the size and type of cupola operation, the in-plant problems, and the reasons behind the selection are presented.

Also covered will be a discussion of the problems encountered with installation and start-up of the control system, and the continuing problems with operations as they become affected by the system. Performance and maintenance characteristics will also be discussed.

by



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CUPOLA EMISSION CONTROLS

& PROBLEMS

by

J. C. Hungate, P.Eng.

At the present time, and for the past few years, in Ontario primarily, collection of particulate matter has been a major cost item on foundry engineering programs and budgets. Initially the collection of emissions from cupolas and other types of melting equipment were considered prime targets, but as these sources became cleared up the emission points from other plant exhaust systems became more noticable. The trend has been to speed up correction of the worst and gradually get at the others.

However, collecting emissions at the source is not the final step in the program. After collecting, whether it be dry or wet, baghouse, cyclone, scrubber, electric precipitator, or any other type of unit, the collected material must be dumped somewhere - and therein lies another problem.

In this presentation, I would like to review the major sources of pollution in a ferrous foundry plant and outline some of the problems in collecting the emissions from these areas. The major sources are in general - the melting system and its auxiliaries, the shakeout area, return sand systems, and fume control in the pouring and cooling areas of an average plant.

We will start with the melting area. This has been the focal point for environmental agencies in both the U.S. and Canada. Many of our provincial codes and guidelines have been developed from American State codes - whether it be by process weight, particulate size collecting efficiencies, or opacity.

The cupola is the major source of emission in a ferrous foundry and the most difficult to capture. For each ton

of metal charged there is stack emission in the range of 15-30# and the particulate size ranges from 1000 microns down to less than 5 microns.

A testing of 3 - 10 Ton per hour cupolas showed a particle size distribution - by weight - as follows;

+60 microns	up to 50%
60-25 "	5 to 13%
25-10 "	4 to 15%
10-5 "	2 to 14%
Under 5 microns	4 to 10%

A larger sized cupola may have a different distribution - possibly a greater % of smaller sized particles.

Generally speaking a medium efficiency dust collector will capture almost all of the +20 micron particles and some of those that are smaller. But only a high efficiency unit will be able to collect all of the under 5 micron particles.

No two cupolas are alike - even if designed and built by the same manufacturer. There are differences in operating procedure, types of scrap, size of charging bucket and charging system, temperature and metallurgical requirements that all contribute to a melting program that will affect the grain loading and stack losses.

In the melting area, apart from the cupola, there are other points of emission, minor by comparison, that are coming up for attention. Coke and stone handling systems, unloading facilities for these materials, coke breeze disposal slagging process (wet or dry etc.). But these are all secondary areas compared to the major cupola problems.

Cupola emissions are largely a problem of nuisance. When analysed it can be readily seen that no emissions are given off that could conceivably injure the health of any person.

Atmospheric pollution has been defined in various A/P codes as any substance emitted to the atmosphere in concentration sufficient to interfere with the comfort, safety, or health of man, or with the full use and enjoyment of his property.

This narrows the foundryman's problem down to one nuisance and a great deal depends on the surroundings - topographical and meteorological conditions of the surrounding area and the land usage.

The problem of selecting gas cleaning equipment for iron foundry cupolas depends on the degree of cleaning efficiency required. For example, if it is merely desired to prevent the deposition of cinders and coarse dust on the foundry roof, a cupola stack washer may be installed which will trap the offending material but permit the intermediate and fine solids to pass through to the atmosphere.

Where a local nuisance or air problem exists, it is essential to trap not only the coarse material but all of the remaining which could be expected to settle over the area in question. The removal of solid particles larger than 0.2 microns can be effectively accomplished. As a particle size decreases the efficiency of the collection generally decreases. A device capable of removing essentially all of the particles larger than 1 micron may be only 50% effective in the removal of the 0.2 micron particles.

In the last analysis, it is the responsibility of the foundry operator to determine his requirements with respect to low, medium or high efficiency cupola gas cleaning equipment. However, it is believed, that from year to year new restrictions on industrial effluents will be put into effect. A decision must be made based on the economics of control equipment designed to meet only present requirements, or equipment that will also satisfy any reasonable future restriction of cupola emissions.

When emission control became a legislated issue many foundries (especially the smaller melters) were unable to meet this additional cost and subsequently closed their doors. The larger manufacturers were able to absorb the cost on a per ton basis but obviously this operating cost is passed on to the final customer.

Many foundries, in the process of contemplating changes to their production methods eliminated their cupola and installed electric melting units where the emission control costs were lower:

Another major source of emission is the shakeout and return sand system. This area differs with each plant mainly because of sand temperatures, volumes of sand, metal to sand ratio, types of sand - synthetic or natural, types of additives and their respective volumetric ratios, methods by which sand and additives are blended and mulled, moisture levels, etc. etc. etc.

The sand preparation system is mainly centred around the mullor. The mullor which may be any one of several types

is usually a mixer with large H.P. requirements that will mull the sand and additives (clay and seacoal) by means of plows and wheels. Moulding sand, to be properly mulled, must have each grain of sand coated with clay. A normal mulling cycle consisting of adding flush water, return sand, clay and seacoal, new makeup sand, additional water and discharging, is approximately 3 to 4 minutes. The mixer continues to operate throughout the total cycle. Batch type mixers have capacities in excess of 100 tons per hour.

Other emission areas are generally from ventilation. The Department of Labour in Ontario has requirements for exhausting of ferrous foundries and these volumes are based on production conditions within the shop buildings.

This requirement is spelled out as-
2500 CFM per ton poured in an 8 hour period
plus
500 CFM for each man in the area.

An example of what this does to the plant environment can be seen in one of our plants where approximately 400 tons of iron is poured off in the space of 8 hours. Exhaust requirements are in excess of 1,000,000 CFM and all of this going straight to atmosphere.

Emission from this type of roof exhaust is at a very low level of particulate matter and consists mainly of fume.

But the volume of exhaust air must be replaced by a greater volume to enable the local exhaust units at the dust generating points to operate satisfactorily. This air replace-

ment is costly and is usually supplied through the use of heated make-up air units, but in some areas where no workers are present it may be possible to introduce cold air. One of the main reasons of failure in dust exhausting systems is the negative pressure that exists within the building. Workers are inclined to close off fresh air inlets to eliminate drafts.

The particulate matter to be collected in a ferrous foundry will range in size from +60 microns down to less than .5 microns. Generally speaking, metallic dusts range in the smaller particle size especially that from electric arc furnaces, where a high percentage of the total emission is in 0.5 micron size. Particles from sand systems are mostly in the +20 micron and are more easily captured.

TYPES OF CUPOLA COLLECTION SYSTEMS

Because of the nature and size distribution of cupola emissions a collector for this application represents a major expenditure. Collectors could range in efficiency from the original spark arrester to an elaborate high efficiency unit such as a baghouse.

Our own cupolas are fitted with a variety of types and the reasons for their selection have been economic as well as efficiency requirements. Let me add here that the collected matter has no economic value and its disposal represents additional cost to the operation.

Three separate cupola operations in the foundry division each have different emission control systems.

Fig. 1. One melting operation consists of two 66" cupolas operating alternate days each with a melting rate of under 10 T/hr. At this melting rate the allowable emission level is 75#/hr. with a 97% collecting efficiency of the +25 micron. This system uses a primary collection for large particles and a multi cyclone unit for the smaller sized particulate matter. Dilution air is introduced at the cupola off take to reduce temperature to a safe level of approximately 550° F. The charge door is large - 55 sq. ft. - allowing additional cooling air to temper the hot gases and also allow the stack burners to function.

This type of system operates well within the allowable levels and is relatively low in maintenance costs, However,

failure of the after burners will create a much darker plume as will the introduction of dirty or oily scrap. Disposal of the dust is not too difficult as the material is dry and collected in two hoppers. One for large size particles, the other for the range of 5-10 microns. The dust is transported in a closed truck by an independent disposal firm.

Some of the problems encountered with this system are from high temperatures, especially in a two cupola system where the cupola selector damper must seal tightly in the off-take duct. Distortion or warpage is a common problem.

An interesting feature associated with this melting operation followed the installation of a balanced blast system on each cupola during 1973. This balanced blast system was installed as a coke saving item and the savings were accomplished. - In addition - we were able to realize lower stack temperatures and a cleaner plume from the reduction in coke.

This system, we feel, can be improved upon if need be through the addition of a baghouse down stream from the multiclone collector.

Cost of this system installed was approximately 125,000.00.

I would like to add that this installation is the final stage of numerous attempts to collect emissions for this pair of cupolas.

The first units installed were wet caps, which were no more than a cone shaped cover with a recycled water curtain through which the effluent gases had to pass. This type of unit is efficient only in removing the larger sized particle - say over 25 microns.

With the arrival of more stringent emission control requirements this system was changed for a wet venturi scrubber and packed tower, sludge ejector, and fan. The theory behind the system was good on paper but because of the high percentage of large sized particles in the distribution, the unit became clogged and was never able to operate for more than a few hours without failure. Subsequently, the equipment was removed at a loss to both the suppliers and ourselves.

The present system was initially designed with a different offtake than that at present, and with lower fan capacity. All in all, the collection of particulate matter from these two cupolas has evolved through 3 different systems and many headaches.

Fig. 2. The second cupola operates at approximately 20 T/hr. melting rate and has a baghouse collector. This is by far our most efficient collector system both in terms of collection efficiency and also in maintenance and operating dollars. Although first cost is high - \$400,000.00 the operating difficulties are minor. The system was installed during the operating year and the final tie is made to the cupola during the summer vacation 1971. It went on line immediately following that vacation period and has never broken down except for minor causes - usually less than $\frac{1}{2}$ day, since then.

The system consists of an extended cupola stack with afterburners - refractory lined off-take for the high temperature gases (constantly in excess of 1550°), a quencher for dropping temperatures to the 575° level - where larger flyash particles are dropped out and collected, low temperature duct, fan and a baghouse consisting of 540 fibreglass bags - 11' dia. x 20'.

There is no exhaust stack on this unit, the fan is on the dirty side of the baghouse and the clean gases escape to atmosphere at the top periphery of the baghouse structure. There are 9 sections to the baghouse, 8 of these are always in operation while one (1) is being cleaned. Mechanical shakers are used to vibrate the bags.

The dust is collected in the baghouse hoppers, disposal is by means of covered dump trucks. This dust is extremely fine and is similar to talcum powder, in appearance.

Efficiency of this unit is estimated at 99%+, collecting all particles over 1 micron in size and most of the sub micron sized particles.

The reason for selecting this over medium efficiency units was the proximity of the plant to a residential area that lies within a few hundred feet. As mentioned earlier the lower operating costs and reduced maintenance have offset the initial high cost.

The exhaust system must be kept dry - this cupola is bottom dropped daily and care must be taken to prevent steam off the dropped mass from entering the baghouse system and destroying the bags.

Disadvantages to this system are floor space requirements and the requirement that adequate control be maintained at all times to safeguard the equipment. Temperature sensors call for heat at the top of the cupola to ensure that all combustibles are burned off before entering the quencher, and the gases must be cooled to protect the fan & baghouse.

Fig. 3. A third cupola installation on 102" water cooled 45 ton per hour cupola, uses the principle of a variable throat, high static pressure venturi wet scrubber. This system consists of stack burners sized at 12×10^6 Btu/hr., refractory lined cupola off-take, a primary cooler to saturate and cool the gases to 165°F where large sized particles are returned to the settling tank, variable throat 52" S.P. venturi scrubber for fine particles, stainless steel lined ductwork, demister and finally the clean gases are taken through a 1000 HP, 100,000 CFM stainless steel fan to the stack. All the water carrying particulate matter is returned by gravity to the settling tank which uses a dual pneumatic pinch valve system to squeeze out segments of sludge as it settles in the bottom of the clarifier tank.

Flocculants are added to this tank to accelerate the settling and the pH is monitored and controlled by means of a caustic soda pump system.

Efficiency of the system is high, collecting almost all the particulate matter, but during colder weather the exhaust steam plume is quite pronounced carrying for a couple of hundred feet.

The advantages of the installation are minimum space requirements with the installation mainly vertical. The wet system captures the miscellaneous odours thus eliminating a nuisance problem and the adjustable throat venturi provides a means of reducing power demand to an optimum level.

Disadvantages are high power and maintenance costs and disposal of wet sludge.

The cost of this unit installed was in excess of \$400,000.00 and the first question that comes back to haunt you is why didn't you go to a baghouse again.

Fluorspar is used as a slagging liquifier in this cupola and input of this material would have required using high priced 'Nomex' bags and the subsequent lower temperature requirement after quenching. Condensation in the baghouse could be caused creating early failure of the bags. In addition, a major requirement on the type of baghouse used is that the quencher be located close to the cupola prior to ducting to the baghouse. Space for this and what would have been an extremely large baghouse was just not available.

The maintenance costs are extremely high on this system. Corrosion and erosion of the primary cooler, venturi, ductwork etc. are continual problems and reworking of these pieces of equipment is a never ending project. We are presently experimenting with other charge materials that may allow the elimination of florspar. But as most of us in this industry are aware, it is a real struggle to get foundrymen to change their practices.

One other problem is the build up of matter on the fan wheel. Under optimum conditions this fan will come to speed in 52 seconds. Any build up on the blades, or on the inlet dampers to the fan, will cause a delay or even failure to reach speed and subsequently trip out the 1000 Hp motor overloads.

We can safely re-start this fan motor only by following sound start-up procedures - that is - allowing sufficient time between starts. A failure to start-up, delays the starting of our melting process, and hence lost production.

Initial start-up at day one of this system presented many difficulties. The inlet vanes on this type of fan must be completely closed in order to get the fan motor to rated speed. This was done. The motor was started and we approached approximately 3/4 speed when the overloads tripped. The overloads were reset, the motor restarted and once again the overloads tripped. Larger size overloads were installed in the starting section of the control panel. Once again we tripped out.

Our immediate concern was that the motor starting characteristics could not adequately match the requirements of the inertia of the fan wheel.

But what we finally found was a shear pin failure in the inlet vanes - as soon as the fan started to draw air the vanes would be forced open creating the overload.

In any one of our cupolas, there is at any time during the melting day, a burden of charge material in the upper zone. A cupola cannot be shut off and put back on stream indiscriminately. A freeze up of partially melted burden is a real hazard to the melting operation. In addition, the cupola cannot be emptied by dropping through the bottom in the event of failure of the emission control system. It has to be melted down and the well properly drained before the cupola blast can be shut off.

In the case of the 102" cupola, there are approximately 80 tons of charge material in the cupola during the normal melting period. The time required to melt this down to a clean well would be approximately 3½ - 4 hours.

A freeze up of this burden becomes more than a simple

hazard. Not too long ago a major power failure occurred that caused a melting stoppage during the operating day. The tuyeres were opened to control the cupola to some degree, however without proper blast air the burden fused into a solid mass that finally had to be dynamited. This removal took six or seven complete days and I might add the cupola shell has never been the same.

There are other types of collector systems for cupolas. A whole range of cyclones and wet scrubber systems. Some with off-takes at the top of the cupola, others with off-takes below the charge door and using a recuperative system to preheat the blast air. Proper location of stack burners also affects the performance of the total system. But the baghouse as earlier outlined appears to be the best alternative.

At one stage electric precipitators were being considered as a means of collecting cupola emissions. But as one user put it after his experiences, "It's the best system in the world for the first few minutes." Nonetheless, the precipitator is very effective in installations where the grain loading is not too excessive and the particle sizes are sub-micron.

One item within the normal operations of a cupola that does create fluctuation is when the charge bucket enters the cupola charge door. The bucket blocks off the upper stack to some degree and allows dust and smoke to escape below the bucket. This belches out into the charging area and escapes from the range of pick up. In some instances, depending on plant layout, foundries have been successful in installing a tunnel immediately in front of the charge door allowing these escaping gases to be

recaptured once the charging bucket has left the area.

A secondary factor is that the stack burners are usually extinguished during this period of air shortage and re-ignite after a few seconds.

Many of the smaller cupolas, have been able to reduce the size of the collector system through partially closing the charging door. The charge is introduced by means of a vibrating feeder or it may be tilted in through a hanging swing door.

TEMPERATURE RANGES & FLUCTUATIONS

Mentioned earlier was the fact that a wide range of temperatures exists at the top of the cupola. Early in the melting day, during burn in of the coke bed, temperatures in the stack will be in excess of 1500°F. During the early charging periods, prior to melting, stack temperatures are low - below 500°F. During normal melting without stack burners they could reach 800°F and during burn down at the end of the day temperatures will be in excess of 2000°F.

The emission control system tries to collect from a continually fluctuating set of conditions, with wide temperature sweeps and a range of particles from sub-micron to in excess of 1000 microns.

Return sand systems, because of humidity conditions at the shakeout area and hot sand are generally controlled with wet scrubber collectors. Since the particle sizes are large compared to these of a cupola, a medium efficiency scrubber will usually be acceptable.

Individual designs of wet scrubbers vary widely. In one type the air flow is upward, the shell round and tall, the water introduction through spray nozzles. In another type, the air flow is downward, the shell rectangular and short, water introduction is by retained water level in the bottom of the unit. Nevertheless, all of the various designs apply four basic principles in the capture of dust.

Particle Size - In general the larger the particle the less likely it is to follow the air stream around a water film, and the more likely to impinge on the film and be collected. Efficiency falls off quite rapidly with the reduction in particle size and density. Within limits chemical composition, solubility, and shape appear to have little effect on the efficiency of the scrubbers.

Particle Velocity - A second factor which effects the ability of a wet scrubber to capture dust is the velocity of the particle. The higher the velocity, the less likely it is to avoid collision. Thus, efficiency of scrubbers is a function of the velocity in the collection area - and is related to the overall pressure drop.

Flow Patterns - A third principle involves the path that the particle and air stream take. The more turns or bends in the air stream, the more likely is the particle to impinge on the water film. Baffles, packing, etc. are used to divert the air stream.

Contact Area - The greater the area of the water-air surface the greater the chance of particle impingement on the water film. For this purpose baffles and high pressure water nozzles are used to maximize the air and water contact.

The type of sand system under control and the degree of combustion that has taken place in a poured sand mould will generally dictate the type of emission control system that can or cannot, be readily used.

A continuous pouring moulding line where the mould sand is in contact with the poured casting for a short period of time (in one of our installations less than 3/4 hour) has a shakeout return sand system of usually high moisture content, and a high percentage of unburned additives. These additives being combustible represent a hazard in the ductwork system. In addition the high moisture causes blockage in the ductwork, and requires regular clean-up maintenance.

The additives in this system that are collected create a problem in the recycling of the cleaning water. The additives are difficult to wet and usually remain on the surface of the settling tank liquid. The collected particulate matter, instead of settling to the bottom of the sludge collector and being drawn off is pumped through the recycle system creating additional problems to the total installation. This recycled water containing an excess of foundry materials blocks the filter media bed and may be ejected from the clean air stack in large blobs of dark coloured slimy material.

In this installation, after experimentation and testing of settling times we found it necessary to scrap the scrubber and install a baghouse.

Since we were handling a humid sand condition we had to heat the offtake points - five in total - by means of natural gas burners and elevate the ducted gases to a temperature above the dewpoint. The system now works quite well but not before we had incurred two separate fires in the duct and baghouse losing all of the felt bags.

When stating the system works well we are really saying that with proper maintenance, clean up, checking of our control points, and staying on top of the problem - including searching for adequate means of unloading the collected dust into containers for disposal the system will operate satisfactorily.

Another return sand system operates at the opposite end regarding contact time with the poured mould. In this plant we pour off approximately 600 tons of grey iron daily and the casting size - ranges from 7 to 25 tons. The moulds are formed with a sand slinger operation, set in a drying oven for 12 hours to drain off excess moisture, and are poured. After pouring, and a necessary time period has elapsed to solidify the casting, the mould is transferred to the shakeout area where the metal casing is removed. The casting with its mould sand in place is left to cool slowly over a 48 hour period.

The sand is then removed, by impact, the casting is transferred by overhead cranes, to the cleaning area. The sand left on the floor is removed to a sand hot pile area by front end loader and wetted down so that it can be returned to the return sand silo. This by means of a preparator, elevator, and sand

belt system.

This sand is hot, with pockets in excess of 1300°F and each time it is handled gives off tremendous amounts of dust, and steam, if wetted. Sand is a good insulator, so that even if the surface of the pile has been wetted, a couple of inches below surface the temperature remains high.

Each time the front end loader turns over the sand a minor steam explosion occurs filling the entire area with sand and dust particles.

The overhead crane handling requirements preclude any attempt to collect dust off this pile in the center of the floor, however, we are now investigating a new piece of equipment on the market that may allow us to cool the sand in a containing vessel and limit the amount of escape dust and heat.

The dust from this sand system is collected only when finally dumped into the sand preparator at the beginning of the return sand mechanical system.

The preparator which combines a vibrating deck, crusher, and screen, feeds to a series of inclined belts, elevator and transfer belt back to the return sand silo. Collection from this system is by means of a wet multiclone collector. The sludge is deposited in a drag chain tank and dumped at an acceptable disposal area by others.

A similar situation exists to a minor degree, one other plant. Here again the pouring space and shakeout are requirements prevent adequate collection at the center of the floor area.

The shakeout sand system uses wet scrubber with a plastic ball media, spray nozzles, and a demister section. Off takes

from a half a dozen transfer points, including the back drafted hood on the shakeout feed into a common duct to the scrubber. The return sand in this foundry is relatively dry and cool and does not clog the system too severely.

Foundries that pour large castings are faced with numerous overhead crane movements, to produce their product. Preparing for the pouring of an ingot mould requires 18 separate crane operations in the pouring bay alone, prior to pouring the casting. One can appreciate that the space below the crane rails must be kept clear of any permanent structures and ductwork.

Ferrous foundries that pour into permanent moulds, such as cast iron pipe plants, do not have the same degree of emission problems. Their emissions are generally limited to the melting unit and cleaning areas. No. shakeout area is required.

CLEANING ROOM DUST GENERATING AREA

Ferrous foundry cleaning rooms use a variety of casting cleaning machines and hand tools. Large castings are generally processed through the cleaning area with hand held chippers and grinders. Occasionally a swing grinder may be used with a rear mounted hood.

Medium and small sized castings are generally processed through blast cleaning cabinets where the fumes, both sand and metal, are exhausted into a baghouse. These cabinets may be rotating table type, tumbling mills, monorail suspension system with robot controls, or a car type blast cabinet with hand held nozzles. But none of these represent a problem of emissions to the atmosphere.

Apart from the difficulties in selecting and installing a pollution control system the foundryman is sometimes faced with external problems that should not really develop.

In one of our installations, after reaching a final agreement with the operators, the manufacturer of the emission control system, and the provincial environmental department, the equipment was approved and installed but because of topography a high stack was insisted upon.

Shortly afterwards, the municipality approved a construction of two high rise apartment building in close proximity to the plant.

As a result, the high stack as requested by environmental department allows the impingement of stack gases on this building in amounts greater than the limits of the code.

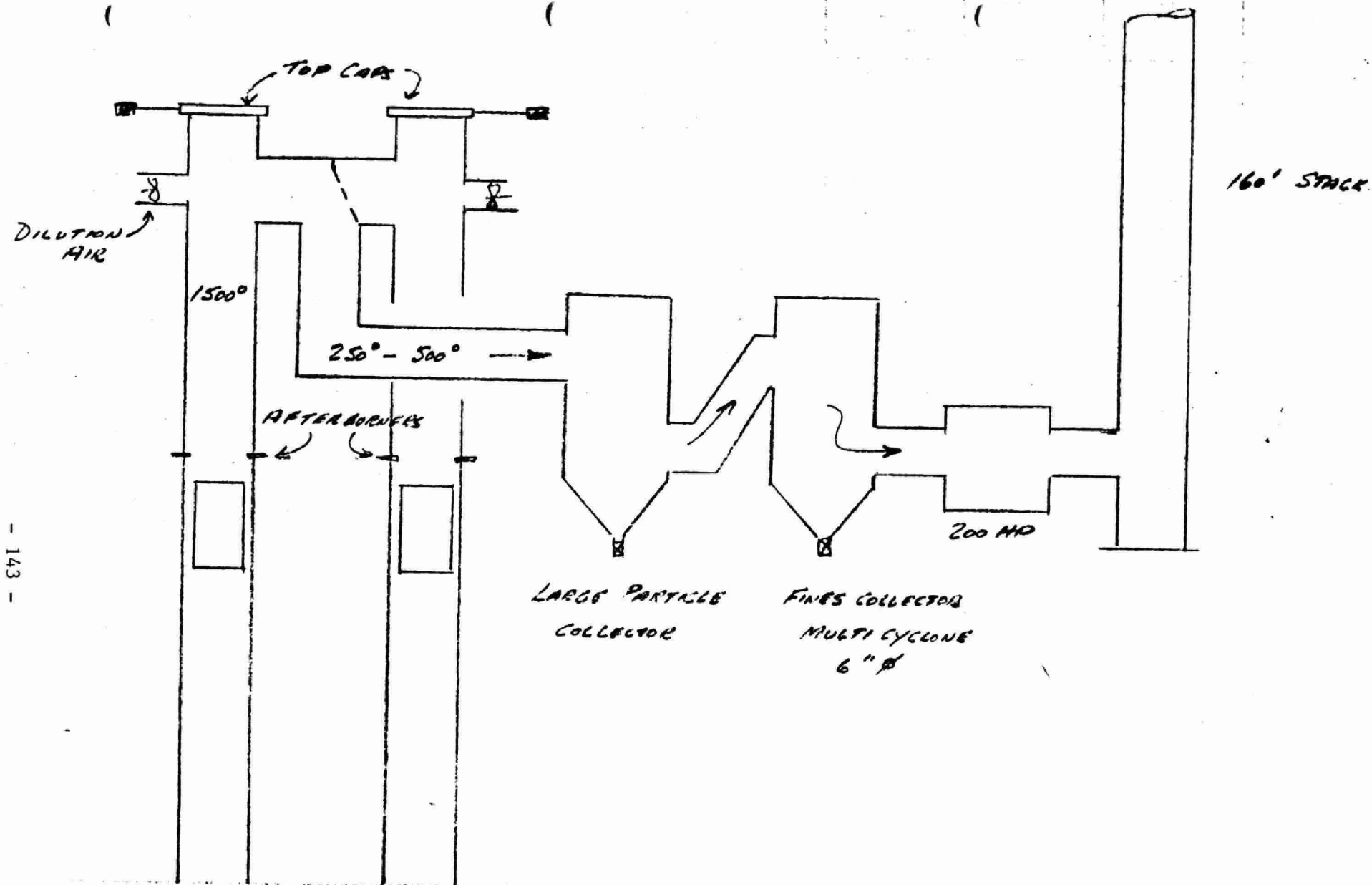
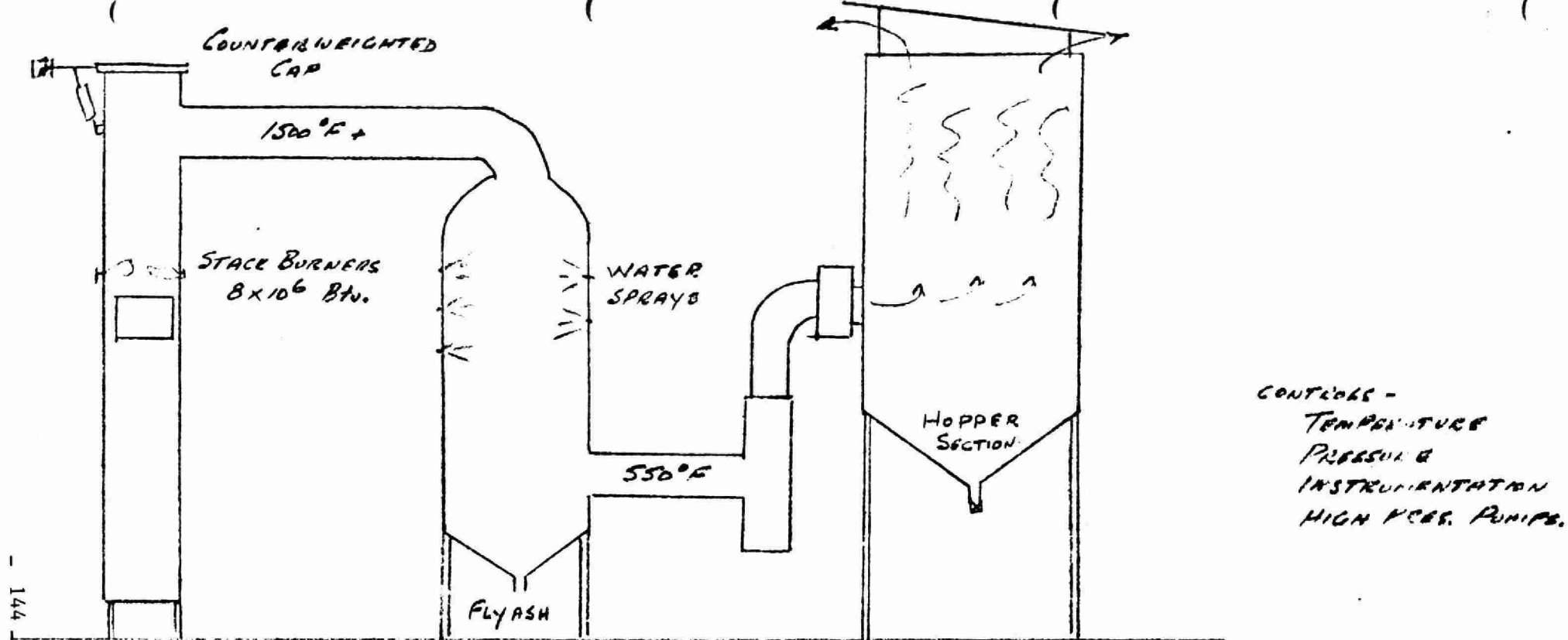


FIG. 1

MEDICAL EFFICIENCY UNIT
DRY TYPE.



CURPLA
20 T/H.

QUENCHER
COOL TO 550°
COLLECTS LARGE
PARTICLES

BLOWER
200 HP
70,800 ACFM
@ 480°

BAGHOUSE 60'x28'x55' HIGH.
540 FIBREGLASS BAGS
20' x 11" Ø

HIGH EFFICIENCY

BAGHOUSE (INSTALLED)

FIG. 2

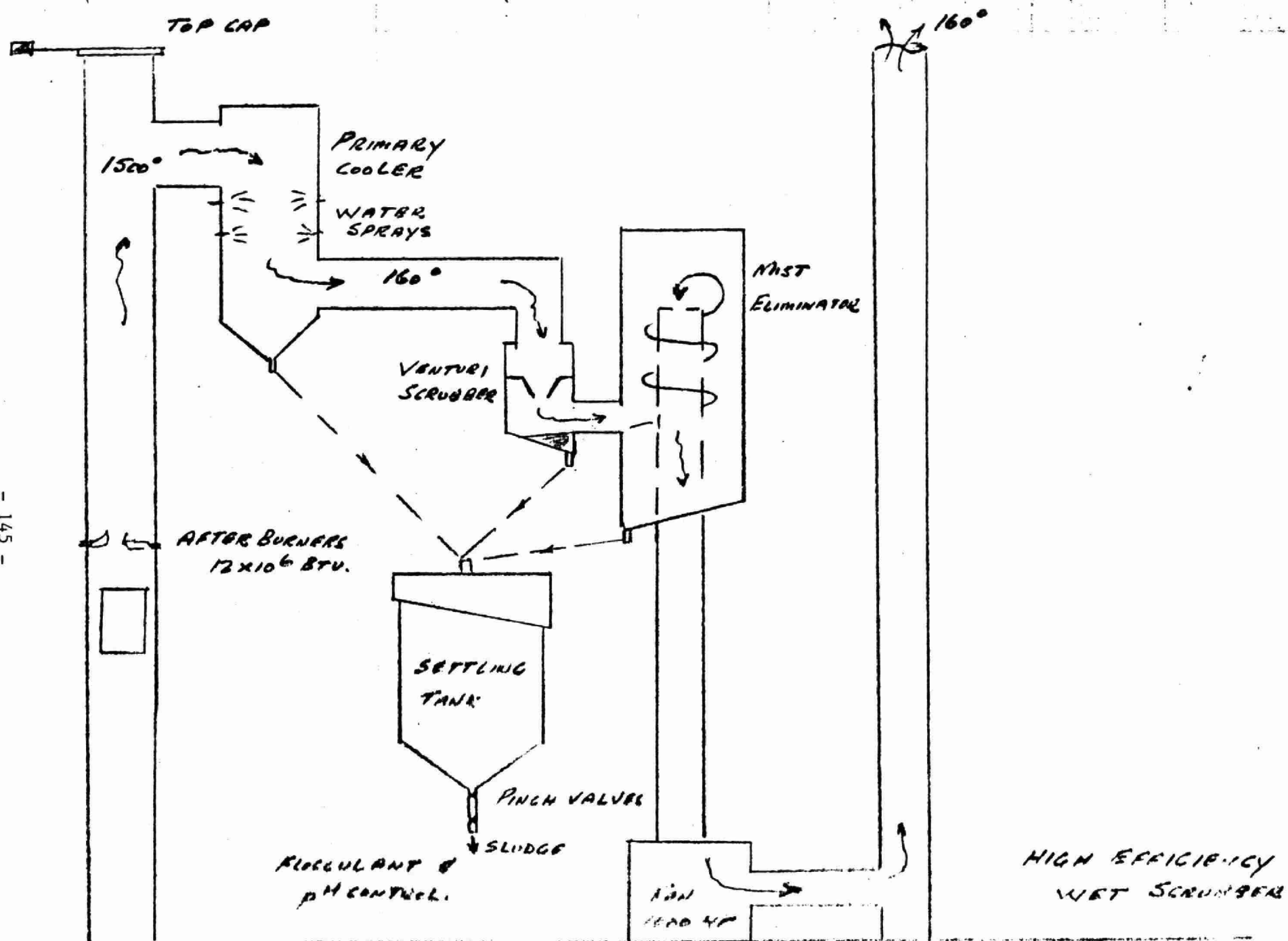


FIG 3

COLLECTION OF FINE PARTICLES;
DEVICES AND THEIR EVALUATION

Effects of particle-surface interactions are prominent on the collection of fine particles from a gaseous suspension. The surface may include that of the collector and that of collected particles. In the category of transient collection devices such as various forms of filters, successful collection calls for large collection efficiency via impact, diffusion, and large depositing force and large sticking probability. The depositing forces include those via electric field, van der Waals force, and fluid force. These devices need renewal by replacement of intermittent cleaning.

by

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COLLECTION OF FINE PARTICLES: DEVICES AND THEIR EVALUATION

by

S. L. Soo

INTRODUCTION

Effects of particle-surface interactions are prominent in the collection of fine particles from a gaseous suspension. The surface may include that of the collector and that of collected particles. In the category of transient collection devices such as various forms of filters, successful collection calls for large collection efficiency via impact, diffusion, and large depositing force and large sticking probability. The depositing force includes that via electric field, van der Waals force, and fluid force. These devices need renewal by replacement or intermittent cleaning. All these devices include large pressure drops. In the category of continuous operating devices with gravity removal, the surface of the devices serves as an intermediate agglomerator. Successful operation, therefore, depends as much on the renewal of the surface as upon the effective collection on the surface. In these devices, large depositing force and large sticking probability do not guarantee efficient operation. The failure of removal of agglomerated particles at the wall causes large carry-over via back corona, fouling of collection plates and corona wires in an electrostatic precipitator, and clogging and surface charge build-up in a cyclone separator. In the third category of positive continuous removal of particles collected on liquid surface are the venturi scrubber, counter-current packed column scrubber, the wet electrostatic precipitator, and the positive cleaning type of electrostatic precipitator using liquid or gas for plate renewal. These devices need water or air or large power consumption. Evaluation of all these devices should be made with reference to a collection efficiency and a power efficiency. Only then, can one have a rational measure of cost-benefit ratio.

When comparing dust collection devices, the practice has been to list the pressure drop of the gas and that of the liquid if used, utilities in power per 1,000 cfm flow, and liquid per 1,000 cfm is used such as given by Sargent [1]. Cyclone separators may even give the impression of having no power consumption. It is readily seen that

1. One inch of water pressure drop of gas is equivalent to
 $(0.118/\eta_b)$ kw/1000 cfm (η_b is blower efficiency),
2. One horsepower per 1,000 cfm is equivalent to 0.746 kw/1000 cfm,
3. One gpm of water consumed is equivalent to

$$60 \frac{\$/\text{gal of water}}{\$/\text{kwh of electricity}} \text{ kw,}$$

4. One psi pressure drop in 1 gpm liquid pumped is equivalent to
 $(0.435/\eta_p)$ watt (η_p is pump efficiency), and
5. One lb/hr of steam consumption is equivalent to 0.075 kw.

For comparison on a common basis, take the following cases [1], for example.

1. Cyclone separator for 5 μ m particles at 95 percent collection efficiency (percent by mass), 4-inch water pressure drop, and assuming a blower efficiency of 80 percent, the equivalent power is 0.59 kw/1000 cfm.
2. Venturi Scrubber for 0.5 μ m particles at 99 percent collection efficiency, 20-inch water pressure drop in the gas, 20 psi pressure drop at 6 gpm water flow, and assuming a blower efficiency of 80 percent, water at \$1.05/1000 gal and power at \$0.02/kwh, and 5 percent loss of water and pumping efficiency of 80 percent, the equivalent consumption is $2.95 + 0.07 + 0.39 = 3.41$ kw/1000 cfm.

3. Electrostatic precipitator for 2 μm particles at 99 percent efficiency, 0.5-inch water pressure drop, and 0.3 kw of electricity/1000 cfm, the equivalent power consumption is $0.074 + 0.3 = 0.374$ kw/1000 cfm.

Hence, users and builders of equipment for the removal of particulate matter from a gas are interested in the following:

1. A strict reference parameter for comparing available equipment in addition to collection efficiency,
2. The basic reason for the energy required in collection, and
3. The ultimate realizable limit of energy requirement for dust removal from a given suspension.

Hence, besides collection efficiency based on mass as we have quoted in the above, it is desirable to identify a power efficiency as in gas separation which is based on minimum work or separation. This is given by a modified Gibbs relation [2] for entropy of mixing (Δs) per unit mass of gas which gives the minimum work for separation at low dust loading as

$$w_m = T\Delta s = (D + D_t)(C/\lambda) x_p [\eta_c (1 - \ln x_p) + (1 - \eta_c) \ln (1 - \eta_c)] \quad (1)$$

for a unit mass of the gas. (Note that for $\eta_c = 100$ percent, $y \ln y \rightarrow 0$, as $y \rightarrow 0$.) In this relation

D is the molecular diffusivity,

D_t , the turbulent diffusivity,

C , the mean speed of gas molecules,

λ , the mean free path,

η_c , the collection efficiency, and

x_p , the "molefraction of particles" which is given by (for mono-dispersed spherical particles) as

$$x_p = \frac{m_p}{m_g} \frac{M_g}{M_{pa}} \quad (2)$$

Here, m_p/m_g is the mass ratio of particles-to-gas in a given volume,

M_g , the molecular weight of gas, and

$M_{pa} = N_o (4\pi/3) a^3 \bar{\rho}_p$ where N_o is the Avogadro number; a , the particle radius; and $\bar{\rho}_p$ is the density of materials constituting the particles.

It is seen that for a static suspension, $D_t = 0$, and $DC/\lambda = RT$ is gas constant and T is the absolute temperature of the gas based on the original reasoning of Gibbs.

The energy efficiency of a dust suspension with a distribution in particle size is readily computed [3]. The above cases are compared to the ideal power requirement in watts/1000 cfm as shown in Fig. 1. In Fig. 1, W_m is the ideal work to separate the particles, W_u is the ideal work to undo the effect of fluid turbulence at a fluid velocity (U_p), and $2a$ is the particle size in μm for silica particles of a concentration of 3 gr/ft^3 at 100 percent collection efficiency. The cause and necessity for the large actual power requirement of devices are worth looking into. One can be certain of one thing: Any claim of performance with power consumption less than that given by the minimum work given by Eq. (1) is as phony as any claim of, e.g., a perpetual motion machine.

To be sure, efficient and economical collection of fine dust particles depends on a finite number of natural phenomena; they are the basic tools for collection and they offer the limitations of development and commercialization. It does well for one to ask the origin of a claim of high performance and to get some straight answers.

PHENOMENA RELATED TO COLLECTION

An ideal system for the removal of fine particles from a gas is one in which the particles simply agglomerate among themselves to reach a size such that they drop out by free fall. Specifically, particles large enough such that their terminal velocity in a given potential field exceeds the flow velocity of the gas readily leave the gas. The potential field may be gravity, centrifugal, or electric. If agglomeration is achieved simply, the cleaning system will be small in physical dimension, low in power consumption, and high in collection efficiency of particles.

The following phenomena are common to all fine particles and their collection [4]:

1. They usually carry electric charges and, depending on their history of handling, may carry a positive or a negative charge of 10^{-5} to 10^{-2} Coul/kg with larger value for smaller particles. This charge may be raised to as high as 100 Coul/kg by intense corona charging of particles below 10 μm in size [5]. Yet, as an application demands, they can be neutralized by using a nuclear ion source. Collection is ^{also} effected by forming dipoles.
2. Especially in a gaseous suspension, inertia of particles is usually felt. Gravity alone is insufficient to settle particles below 10 μm in size at any useful speed and unable to settle particles below 1 μm because of Brownian diffusivity. Inertia plays an important part in impaction and filtration of particles above 1 μm in size.
3. Centrifugal force can give an acceleration many times that of standard gravity. The force per unit mass (acceleration) acting

on a particle must be paid for in pressure drop such as in a cyclone separator: $v^2/R \approx \Delta P/\rho R$ where v is the tangential velocity to be maintained at radius R ; ΔP , the pressure drop; and ρ , the fluid density. One drawback is that the fluid velocity decreases to zero at a surface such as in a cyclone separator thus giving the particle a "soft landing," and particles below $1 \mu m$ will not deposit because of Brownian motion. Hence, a centrifuge is more effective than a cyclone for collecting fine particles although mechanical arrangements for continuous centrifuging of fine dust from a gas are difficult.

4. During collection of charged particles in an electric field, either an external field or that due to space charge, the particle makes no soft landing and the collection tends to be tenacious or too tenacious. The problem is often in their subsequent removal.
5. Particle-particle agglomeration requires large relative motion, and high collection efficiency by mutual agglomeration of particles will always be limited by the lack of collisions among the particles as they are removed.

Agglomeration of a particle cloud with a distribution of particle sizes can be produced in an accelerating or decelerating fluid which produces relative motion between large and small particles because of their difference in inertia [4]. Collision or scavenging of small particles by large particles leads to an increase in particle size. A distribution in size is not necessary when sonic agglomeration is used. Sonic agglomeration is

effective even for small particles of $0.1\text{ }\mu\text{m}$ size. However, particles must be close together for collisions to occur, and high particle concentration (say, 1 gr/ft^3 for $1\text{ }\mu\text{m}$ to $10\text{ }\mu\text{m}$ particles) is needed. Large power consumption of 3 kw/1000 cfm of gas treated was indicated [6].

One way to improve the situation is to increase the collision surface by introducing liquid droplets such as in a venturi scrubber. Such a scheme is feasible if a liquid can be used. The power consumption is high, say 5 kw/1000 cfm of gas treated, and water (when used) still must be paid for [3].

6. Surface adhesion is especially important to collecting from a dilute suspension. Here, the collection or collision with the wall of the system will become more significant than mutual collision. Therefore, designing for removal of particles from a gas calls for a knowledge of the interaction of the gas, the particles, and the wall surface.

The next approach is to introduce additional dry surface for collection or agglomeration. A fluidized bed of pellets may be used but clean pellets must be regenerated. Surfaces that are easily regenerated must have simple geometry. The obvious answer is a surface such as in a cyclone separator or an electrostatic precipitator. In these well-known devices, the collecting surfaces may also be viewed as agglomerating surfaces which build up layers of particles over a length of time. The surface is then regenerated by the removal of the particles in lumps (or agglomerates) into receptacles such as bins. The power consumptions of these devices are in the range of a fraction of a kilowatt per 1000 cfm of gas treated.

7. Surface force between a particle and a solid surface exists because of fluid force via viscosity and surface tension, electric force depending on conductivities of surfaces, or the van der Waals force. The latter is given in terms of a force per particle ($= c_w a$) acting over distances of Angstroms where c_w is the force per unit radius, a , of a particle. C_w is nearly 0.01 dyne per μm radius for quartz on glass [7]. Data are not plentiful on any of these surface forces of various material combinations. The above value gives a terminal velocity due to van der Waals force of 265 m/sec for particles below 1 μm size [8,9]. This means fines stick to a surface tenaciously once they are deposited. Re-entrainment tends to occur to fine particles near the wall prior to their sticking [10,11].
8. Fine particles have diffusivity even in a quiescent gas by Brownian motion and in laminar and turbulent motions of a fluid. [12]. A particle gets near a solid surface and will be collected by van der Waals force or near a liquid surface by fluid force. Diffusion modifies the behavior of impaction significantly [13] and is an important factor in the filtration of particles [14].
9. Other phenomena relating to collection of particles are thermal phoresis, diffusion phoresis, and electrophoresis. These effects are not often used in a large scale collection [4].

CONTINUOUS COLLECTION

Any claim of a device which can operate continuously often needs close scrutiny. Dry filters, even those which are renewable, are not capable of continuous operation. Claims on performance of filters are usually straightforward. Packed bed filters using continuous liquid removal of particles, liquid spray devices, wet electrostatic precipitators using liquid films, and venturi scrubbers using high velocity liquid droplets usually can satisfy the claim of continuous operation without much problem except that among this group, a device has either low collection efficiency (below 90 percent for 0-2 μm) or large power consumption (up to 10 kw/1000 cfm) or both (wet electrostatic precipitators) [15]. These continuous-operation devices have one common factor: Water or another fluid [16] is needed for the continuous renewal of collector surfaces. Except for the case with separate passages [16], they are not useful where gas is not to be cooled.

Problems of claim of continuous operation arise in those devices using gravity as the main effect for the renewal of collector surfaces. This category includes the conventional electrostatic precipitator with the help of rapping and the cyclone separator with or without the use of a vibrator or a scraper. Continuous operation cannot be maintained if the collected particles fail to disengage and fall due to gravity. An electrostatic precipitator may perform at the specified 98 percent collection efficiency for less than two hours starting from clean condition. Under such circumstances, the device can hardly be considered to have a continuous rating of 98% efficiency although it may operate continuously at 70 percent efficiency [15]. A cyclone separator, to perform continuously, must unload the collected particles continuously although it is not

normally designed for collecting particles below 5 μm [1,17]. Its performance rarely breaks down because of carry-over by gas flow or turbulence; however, it breaks down more often because of build-up of particles to

- (a) Form an electrostatic charge layer on a thin layer of deposit to resist further deposition which occurs quickly after starting from the clean condition **or**
- (b) Form a thick layer (sometimes this had to be chiseled off) to change the flow condition significantly to produce large carry-over by gas flow. This may happen after weeks of operation.

Condition (a) is far more bothersome. In one case, the penalty to a contractor for loss of catalyst was \$1 million per month.

When applied to environmental control, one can "buy away" trouble depending on the legislation. Recent trends, such as in Illinois, are to have the user assume the responsibility for the claimed performance. Relations of various factors to the performance of filters, electrostatic precipitators, and cyclone separators are discussed next.

RELATIONS OF VARIOUS PARAMETERS TO COLLECTION EFFICIENCY

FILTERS

The fact that collection of fine particles occurs in filters formed by either fibers or pellets with openings larger than the particles shows that the collection of particles in these cases occurs via electrostatic forces, surface forces, and diffusion. For fines, the fraction impacted due to inertia could be negligible. While fraction impacted by inertia is well known, the filtration of fine particles often occurs mainly by diffusion such that, for complete sticking on a collection target of spherical pellets [18],

$$\eta_D = 8(D_p/D_c u_o) [1 + 0.64 (D_p/D_c u_o)^{-1/3}] \quad (3)$$

where D_p is the particle diffusivity,

D_c , the diameter of the collecting pellet, and

u_o , the interstitial velocity of the fluid.

For sticking by van der Waals force (of f_w per unit mass) alone at sticking probability σ_w [13], we have

$$\eta_{Dw} = \eta_D [1 + (2F D_p/\sigma_w D_c f_w)]^{-1} \quad (4)$$

where F is the inverse relaxation time of momentum transfer of fluid to particle. The relation can be similarly modified for filtration with an additional electric field. As the filter cake grows, it will have increasing collection efficiency at increasing pressure drop.

The above relations show that individual collection efficiency of a pellet can have a value greater than 100 percent and a large value for large diffusivity, small pellets, and a low flow velocity as expected. When the sticking probability is finite, large sticking probability ($\sigma_w \approx 10^{-4}$), target diameter, and sticking force, and large particles (small F) are desirable

in achieving good collection efficiency. The initial overall collection efficiency of a packed bed of pellets of depth L is given for η_D or η_{Dw} (given in Eq. (3) or (4)) by

$$\eta_c \approx 1 - \exp [-\pi(4 - \pi)^{-1} \eta_D L/D_c]. \quad (5)$$

Showing the importance of large η_D , large L to give large η_c will cause large pressure drop.

ELECTROSTATIC PRECIPITATORS

The present configuration of conventional electrostatic precipitators was introduced in 1906. The basic design of a conventional precipitator leads to its limitations.

A plate-wire type precipitator consists of an assembly of collector plates with a row of high voltage charging electrodes mounted between each pair of plates and the entire assembly mounted in the dust laden gaseous stream. Since the plates are cleaned by rapping and dropping of collected dust by gravity, they are required to be separated at a sufficient distance for the free fall of the dust. This leads to distances of 4-5 inches from the corona wires to each plate and a high voltage of 50-75 kv is necessary to produce the desired corona discharge [19]. To a lesser extent, a tubular (corona wire-in-tube) configuration has also been used; the basic features, however, are similar.

In power plant applications, the efficiency of a precipitator for flyash is sharply influenced by the content of sulfur in coal. For a design efficiency of 95 percent for 5 percent sulfur in coal, when low sulfur (0.5 percent) coal is used, the operating efficiency might become as low as 70 percent [20]. The effect of reduction of sulfur in coal on precipitator efficiency at a gas temperature of around 300°F is shown in Fig. 2. Data from various sources were plotted for comparison [20,21].

The Consolidated Edison design data and the TVA measurements show agreement in trend for 100 ft² collection area per 1,000 cfm. High efficiency at low sulfur percentage calls for drastically increased collection area to above 300 ft² per 1,000 cfm or substantially elevated gas temperature [21].

Degradation of the usually specified efficiency also occurs in the course of operation due to dust build-up. This is because rapping does not provide for positive cleaning of electrodes. Starting with a clean unit, a progressive increase in precipitator loss from 15 minutes to two hours, 4 hours, and to the ultimate condition of continuous rapping may mean an increase in loss of from 2-4 percent, yet the corona power input might be doubled from 30 w to 70 w per 1,000 cfm [19].

Successful rapping depends on a certain range of conductivity of flyash or other dust material at various temperatures. The resistivities of various dust materials are shown in Figs. 3. Figure 3a gives the resistivities of flyash for various ranges of sulfur in coal [21-23]. Figure 7b shows the resistivities of cement dust of various moisture contents [24,25] and the ranges of incinerator dust [26,27]. It is seen that the latter two, over a range of temperature, correspond to high sulfur coal, whose ash has sufficiently low resistivity. The precipitator is more efficient at such a level of resistivity because rapping is more effective than otherwise. The higher reported efficiency of precipitators in cement mills or incinerators than in power plants is also because of their average dust loading, which amounts to from 3 to 20 gr/ft³.

In the long run, escalating control regulations will push for measures in terms of flux of particles in parts per million rather than levels of efficiency which have been used as a measure of precipitation performance.

It is, therefore, deemed desirable to consider the inherent design features which produce precipitation inefficiency. They include the electrohydrodynamic performance and the manufacturing accuracies.

Among these topics, the most frequently mentioned is turbulence. With the plates separated at 8-inch intervals, the accepted optimum gas flow velocity is approximately 5-10 ft/sec. This gives a high Reynolds number based on the gap between plates causing re-entrainment of collected dust by turbulence. Rapping also causes re-entrainment of dust. Extremely high efficiency may call for closed-cell rapping. The influence of diffusion on deposition will be discussed later.

The number of wires between each two collector plates has to be large to insure a high opportunity of having the dust charged because of re-entrainment by flow turbulence mentioned in the above and re-entrainment by electric wind normal to the flow direction [29].

Non-uniformity of the corona discharge arises because of a wire which is slightly off centerline between the plates and is subject to an electric force to push it further away from the centerline.

It was shown even with an installation accuracy of within 0.01 mm at the wire support, a deviation of 8 mm from the center may occur over a 5 m long wire. There is, hence, a variation in the distance between wire and plates along each wire [15]. This reduces the effective passage height or tube length of a tubular precipitator. Therefore, large numbers of wires are used between each two plates so that at least some wires are at an equilibrium position near one plate even if most of the wires are nearer to the opposite plate. A further assurance of corona is by operating at an arc rate of up to 100 arcs per minute over the whole unit [29]. Such an arc rate causes ozone generation, another factor in air pollution.

The need for both large frontal area, long flow passages, and large numbers of wires makes the conventional precipitators large and bulky in size.

Because the electric field is normal to that of gas flow, the corona current decreases with increase in dust loading, resulting in low operating efficiency at excessive dust loading [29].

The basic configuration, even in tubular form [30], is unsuitable for high temperature, high pressure design that might be needed in a precipitator installed ahead of a preheater or for a coal burning gas turbine plant with ash removed ahead of the turbine.

The interrelation of various factors to the collection efficiency of an electrostatic precipitator has been determined [31]. It has been shown that

1. When the drift by electrostatic force is small compared to that by diffusion, the collection efficiency is given by

$$\eta_c = 1 - \exp [-\sigma(q/m) \cdot E/FU \cdot L/b] \quad (6)$$

for sticking probability σ , charge q , and mass m of each particle, electric field E , inverse relaxation time F is particle in gas, mean flow velocity U , passage height $2b$, and passage length L , which is the Deutsch equation [32] with modification by the sticking probability.

2. When the drift by electric field is large compared to that by diffusion, the efficiency becomes

$$\eta_c = 1 - \exp [-(q/m)^2 \cdot (E^2 b/4F^2 D_p) (L/b)] \quad (7)$$

where D_p is the diffusivity of particles. Here, the collection is not strongly influenced by the sticking probability; the influence of particle diffusivity is readily seen. Space charge effect is neglected in the above, which is appropriate for a dilute suspension.

Although Eq. (6) is used often, Eq. (7) is more realistic. These relations show how the phenomena outlined above are related in this application. Equation (7) shows that collection can always be enhanced by the parameters involved; however, the real challenge is in the successful removal of the collected particles from the plates. Wet electrostatic precipitators are not useful where gas is not to be cooled, and mixing of high voltage and water in the same region often spells trouble. A new possibility is shown by a recent study [16]; however, additional development effort is needed for large capacities.

CYCLONE SEPARATORS

The basic relations also make possible the analysis of performance of a cyclone separator on a rigorous basis. As shown in Fig. 4, a common configuration has dusty gas entering tangentially at the top of its cylinder section to produce the vortex motion. The particles collected by the combined centrifugal and gravity forces are removed at the bottom of the conical section. The cleaned gas exits from the top.

Figure 4 shows the coordinates and dimensions of the flow system for flow volume per unit time Q ; radius $R(z)$ of the inside surface with

coordinate r, z in the radial and axial directions, respectively; velocity components u, v, w in the radial, tangential, and axial directions, respectively, for the fluid phase; and $u_p, v_p,$ and w_p for the particle phase of a given species. The fluid motion is readily calculated as described in Fig. 4a. Vorticity of the system is denoted by C .

The density distribution of the particle phase is strongly influenced by a finite particle diffusivity D_p and field forces, together with sticking probability σ of particles at the wall or with the deposited layer of particles [4,11]. The field forces include centrifugal, gravity, and electrostatic forces. The effect of electrostatic charges is prominent in gaseous suspensions. The electric charge effect is such that much of the carry-over into the outlet pipe occurs due to electrostatic repulsion rather than by turbulence alone.

The collection efficiency can be expressed, for a steep cone, as

$$\eta_c = 1 - \exp \left\{ -\sigma \left[\left(2\pi C^2 L/F Q R^2 \right) + 8\pi(\rho_{p1}/\epsilon_o) \left[(q/m)^2 \right] \right. \right. \\ \left. \left. (R^2/F) (L/Q) + 2\pi E_o (q/m) (RL/FQ) \right] \right\} \quad (8)$$

where ρ_{p1} is the density of the particle suspension at the inlet and ϵ_o is the permittivity of free space for length L , radius R , and volume flow rate Q . Note that $C^2 L/18 F Q R^2$ is just the cyclone number of Rietema [33]. The relation also explains the choice of the Tengbergen group which is just $9C/F R^2$. In general, $\sigma > 0.01$ may spell trouble for proper unloading. Some agreement of these chosen dimensionless groups with experimental results is, hence, not surprising. Other terms in Eq. (8) show that by a combination of centrifugal force and electrostatic forces, a large diameter ($2 R_o$) cyclone may have the same efficiency as a small cyclone separator for a gaseous suspension.

For particle size $2a = 10 \mu\text{m}$, viscosity of the gas, $4 \times 10^{-6} \text{ kg/m-sec}$; density of gas, 5 kg/m^3 ; and density of particle material, $1,370 \text{ kg/m}^3$, relaxation time $1/F = 2 \times 10^{-3} \text{ sec}$. For $\rho_{p1} = 2.98$, $(q/m) 4 \times 10^{-5} \text{ coul/kg}$. Take two cyclones, one 25 cm in diameter and the other 150 cm in diameter for $\rho_{p1} = 2.98 \text{ kg/m}^3$ pressure drop 1.2 psia, $q/m = 10^{-4} \text{ coul/kg}$, the acceleration at R_o , due to centrifugal and electrostatic effects of the two and their efficiencies are given in Table 1. Because of the space charge, for a similar pressure drop, a large cyclone separator may even have higher efficiency than a small one.

The ideal situation would be a dense bed collection by either the centrifugal or the electric field and the bed be non-adhesive so that a sliding bed flows down the cone toward the dust discharge as is shown in Fig. 4b. This is not always the case, however. Plugging of the outlet and refusal of the collected dust to unload can be the most frustrating problem to solve once an installation is constructed.

Unloading of the collected particles at the bottom of the cyclone is simple and similar to the condition of unloading of bins and the flow of solids through an orifice; often the pressure is lower on the inside of the bottom cone. The difficulty is usually to get the collected layer to slide down from the upper portion of the cone.

For a sliding bed of collected particles of thickness δ_s (coordinate y in Fig. 4), relations of mass balance and force balance give, for a steep cone

$$(\delta_s/R_o)^3 \approx [(\sigma \mu_s D_p/g \rho_{ps} R_o^3) (\rho_{p1}/\rho_{ps}) (y/R_o) (\Omega + \pi\alpha/\cos \phi - f \sin \phi)] \quad (9)$$

where $\delta_s = 0$ at $y = 0$, g is the gravitational acceleration, ϕ is the cone angle, ρ_{ps} is the sliding bed density, f is the Coulomb friction coefficient at the wall, μ_s is the shear resistance of the sliding bed, ρ_{p1} is the inlet

density of the particles, and $\bar{\rho}_p$ is the density of solid material. δ_s increases toward the bottom of the cone. Ω and α are given by

$$\Omega = C^2/R_o^2 D_p F, \alpha = (\rho_{p1}/\epsilon_o)(q/m)^2 (R_o^2/D_p F)$$

for the effect of fluid force and electrostatic flow, respectively.

CONCLUSIONS

This presentation has attempted to outline a framework via which rational evaluation of devices for collecting fine particles from a gas can be carried out. This can be accomplished by the following:

1. Outlining the primary factors having influence on collection efficiency to remove mysteries introduced by promotional efforts,
2. Identifying what needs to be paid in terms of power efficiency,
3. Furnishing questions to be asked of suppliers and items to be checked with respect to claims, and
4. Showing parameters and directions in which they might be juggled in development effort or in trouble shooting.

Especially in the area of continuous operating collecting devices, there are very few standards that are available with respect to devices and their applications. "Users beware!" includes a caution against misunderstanding as well as misrepresentation.

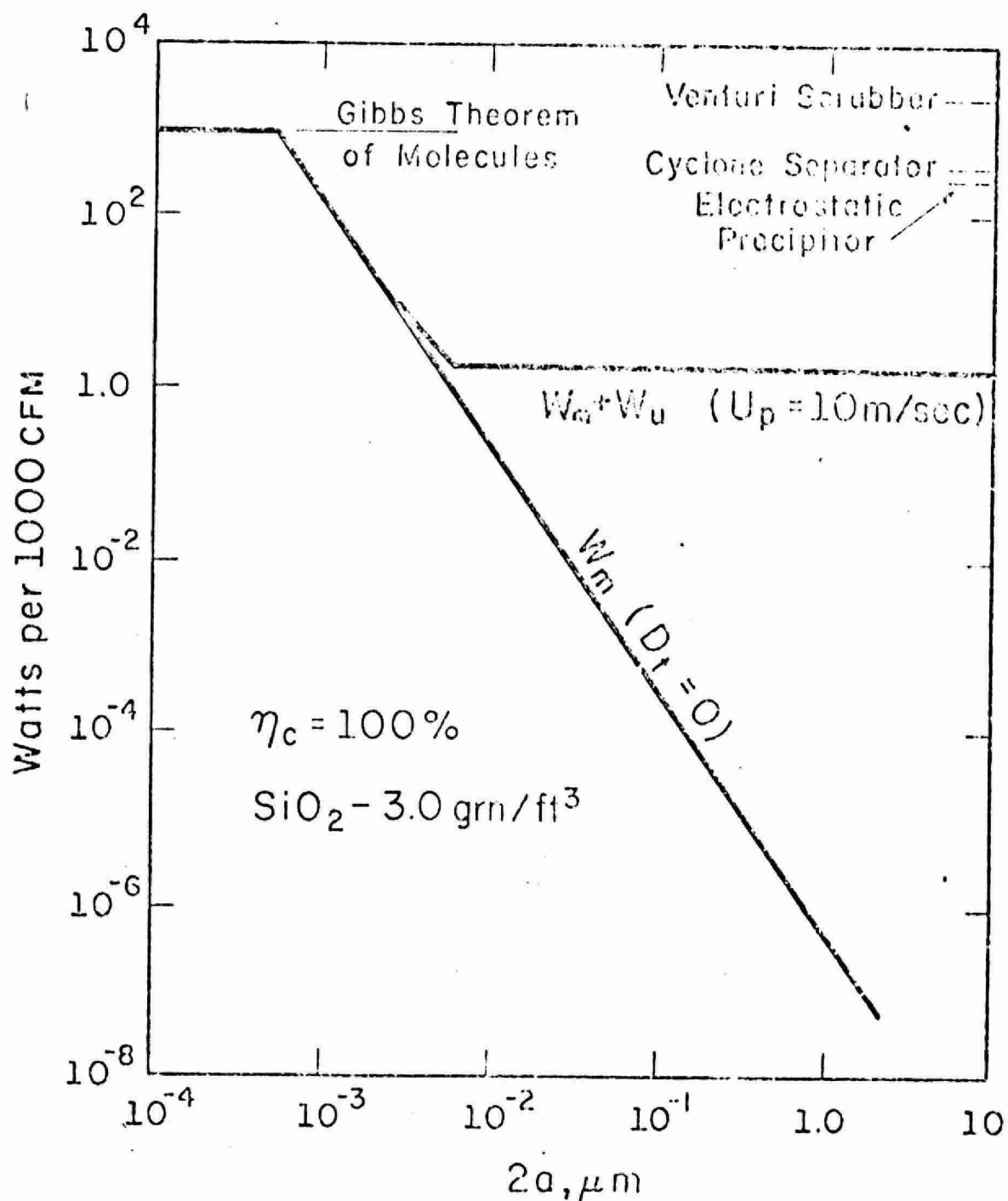


Figure 1 Minimum Power for Collecting 3 gr/ft^3 of Silica of Various Sizes in Comparison to Power Requirements of Practical Devices (Power Input is in watts per 1,000 cfm Air Flow [3])

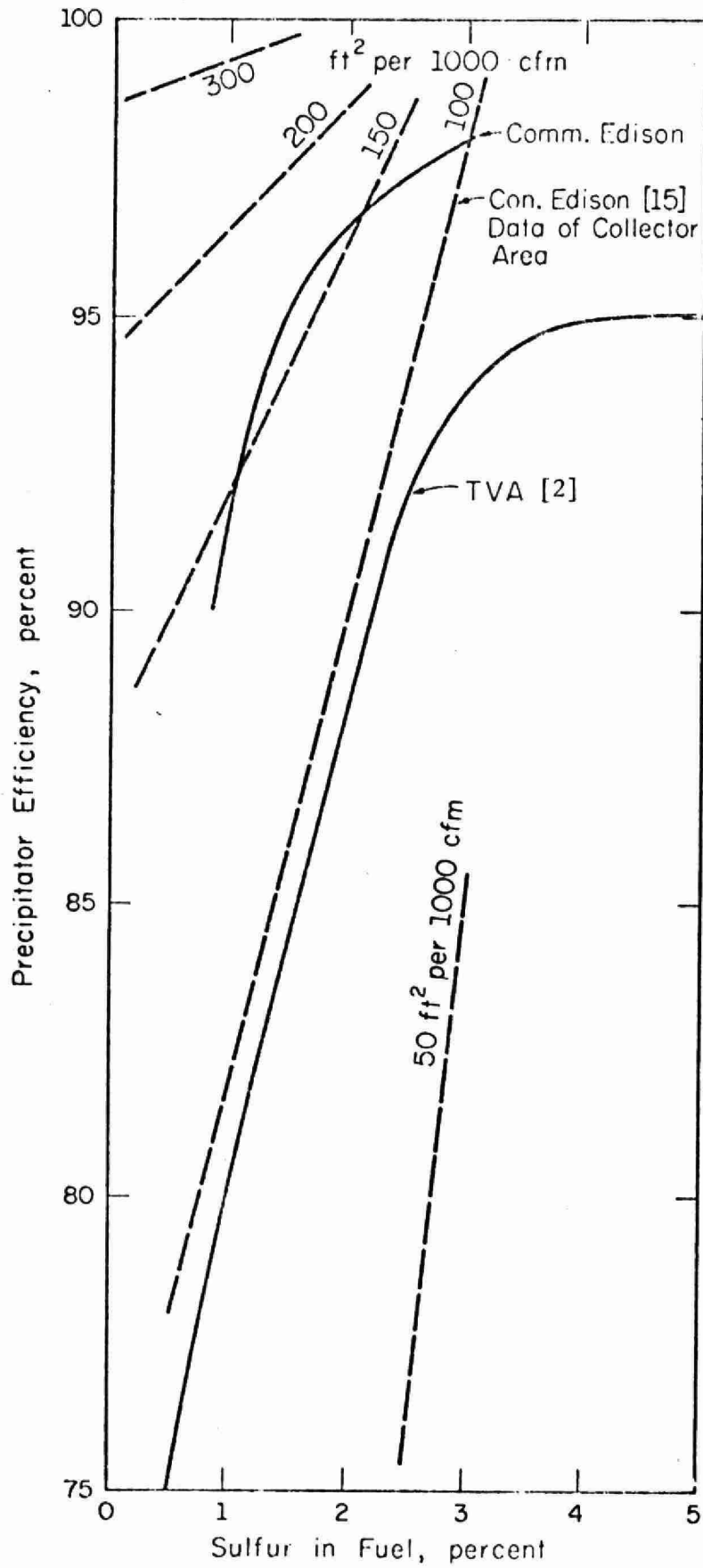


Figure 2 Precipitator Efficiency as Influenced by Sulfur Content in Coal

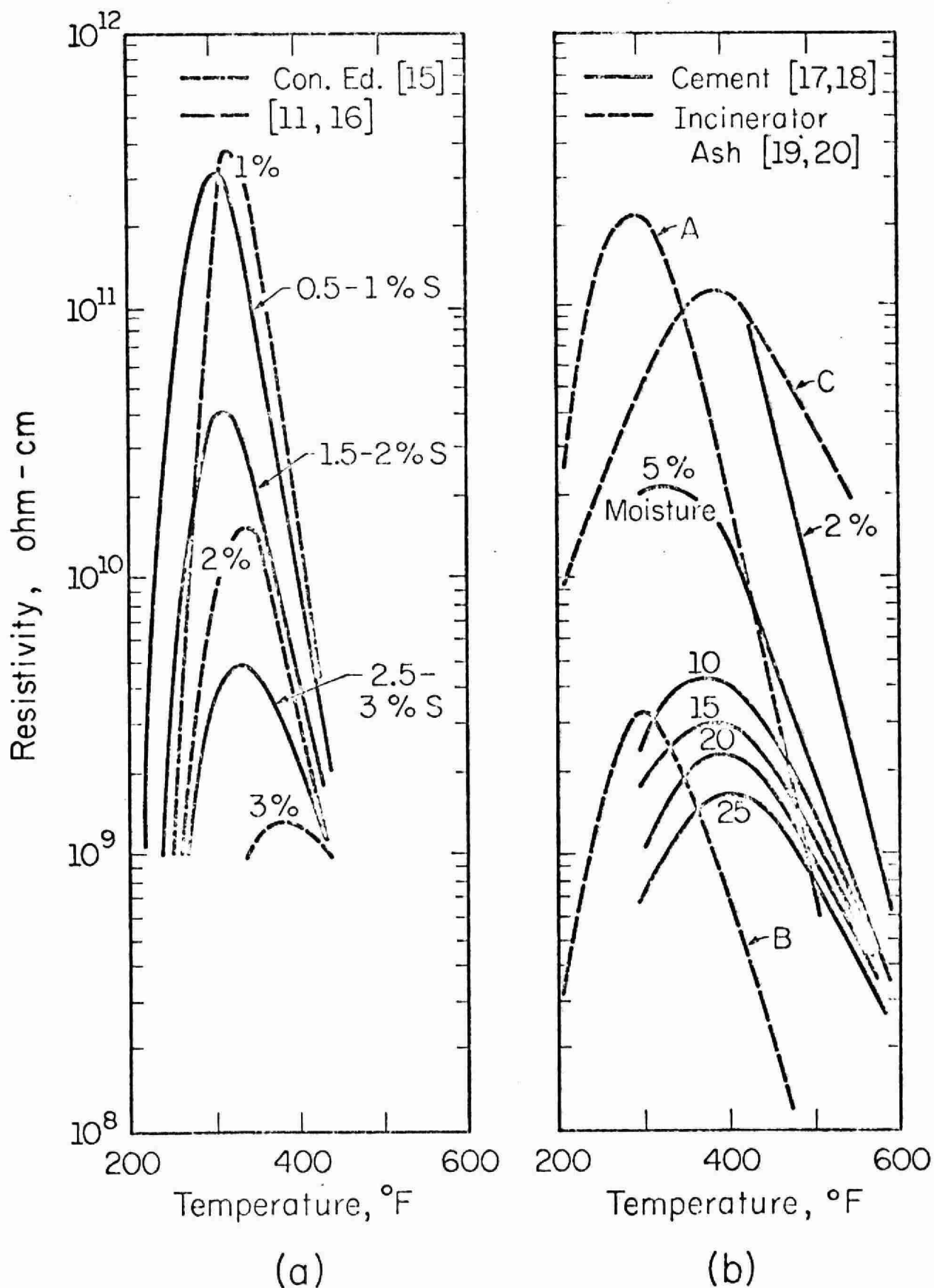
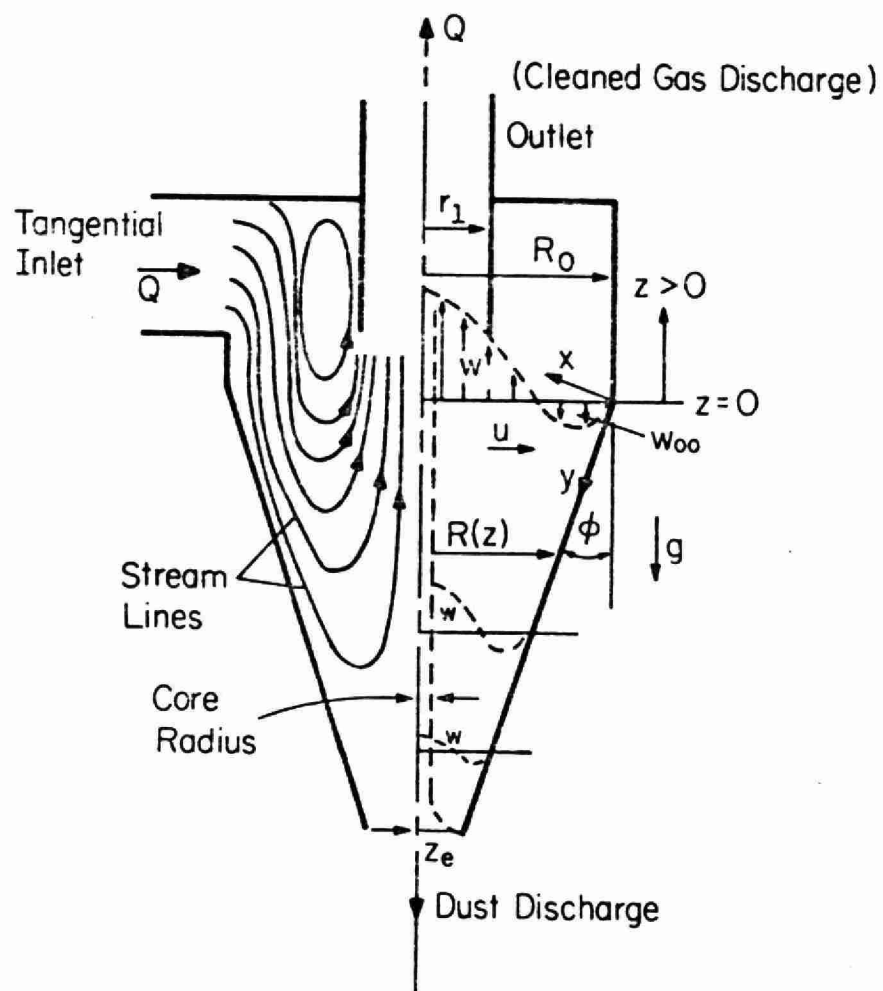
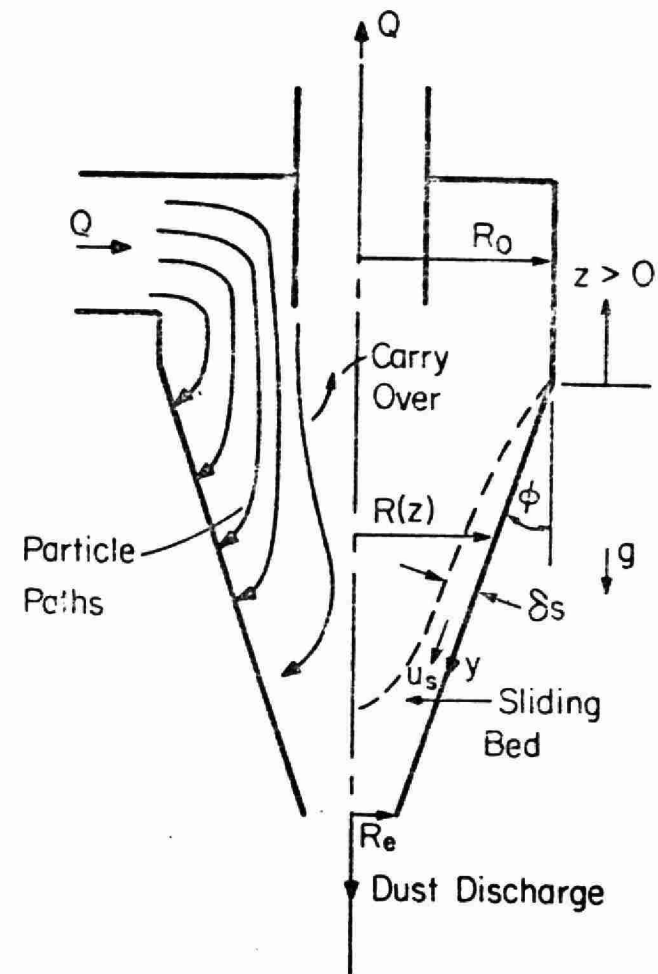


Figure 3 Resistivities of Various Dusts
 (a) Flyash
 (b) Cement and Incinerator Dust
 A-B Range below 74 μ m Fraction [19], C, 45° Dew Point [27]



(a) Fluid Velocity Distribution



(b) Particle Path and Sliding Bed

Figure 4 Conditions Inside a Cyclone Separator and Coordinates [31]

Table 1 Centrifugal and Space Charge Effects
in Cyclone Separators

Diameter, $2 R_o$, m	0.25	1.50
Q , m^3/sec	0.178	6.43
C , m^2/sec	4.17	31.1
L , m	0.875	5.25
Acceleration at R_o due to centrifugal force, m/sec^2	13,100	2,180
Acceleration at R_o due to electrostatic force, m/sec^2	1,330	7,950
Total acceleration, m/sec^2	14,430	10,130
$\frac{2}{F} \frac{C^2}{Q} \frac{L}{R}$	68.4	0.32
$\frac{8\pi \rho_{pl}}{\epsilon_o} (q/m)^2 \frac{R^2}{F} \frac{L}{Q}$	1.29	77.8
σ	0.05	0.05
η_c , Eq. (8)	97.3%	98%

NOMENCLATURE

a	radius of a particle
b	constant or width
C	vorticity
D_p	particle diffusivity
E	electric field, modulus of elasticity
f	Coulomb friction coefficient or distribution function
F	inverse of relaxation time or relaxation time constant for momentum transfer between fluid and particles
g	gravitational acceleration
L	length of passages
m	mass of a particle
q	electric charge per particle
Q	volume flow rate
R, R_o	radius of wall
t	time
u_o	maximum or core velocity of fluid phase
V	electric potential
ϵ_o	permittivity of free space
ρ_p	density of particle cloud
$\bar{\rho}_p$	density of material constituting particles
σ, σ_w	sticking probabilities as defined
ϕ	azimuthal angle or slant angle of cone or work function

Superscripts

- material or mean quality

Subscripts

l initial condition

o reference value

p particle phase

s deposited phase

w wall condition

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COLLECTION OF EMISSIONS FROM A COKE OVEN

This paper covers the control of emissions that occur on a coke over and particularly on the coke side of an oven. It gives as a preliminary, a description of a coke oven battery and describes the origins of these emissions. The methods of control include the various types of collection devices that are employed and deals with the design characteristics of one of these. It also deals with the types of emissions collected, and the methods of removing these from the air. Also, taken into consideration are the effects on workers' health of these types of installations.

by



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COLLECTION OF EMISSIONS FROM A COKE OVER

by

Dr. John A. Standidge

Some five years ago I gave a paper at a conference outlining the difficulties associated with the control of emissions from coke ovens. Since that time, certain progress has been made, and I would like to discuss that progress today.

Firstly, coke is a relatively non-volatile carbonaceous residue that results from the destructive thermal distillation of coal. Approximately 99% of North America's annual coke production is made in slot ovens. The slot oven is a chamber approximately 18" wide with a height of between 10' and 24', and between 35' and 55' long. A number of the slots are incorporated into what is generally referred to as a battery. The number usually varying between 40 and 90 ovens. Coke produced in slot ovens is used in the integrated iron and steel industry, and the grey iron foundry industry. Most coke plants are located at integrated iron and steel plants, and produce blast furnace coke. The remainder are usually producers of foundry coke, and are often referred to as merchant coke plants.

I would like to discuss this morning, emission problems associated with one aspect of the coking process, and approaches that are at the moment taking place to reduce and control these emissions. The area I want to talk about is the emissions on the coke side of the battery. These emissions can be broken down into two categories. The intermittent emission from the "discharge" or "pushing" of an oven which can occur at intervals of from 6 to 20 minutes throughout the whole 24 hour period; and the emission of gases being evolved from leaking doors. Several different systems are being used or installed to control emissions from the "pushing" operation on the coke oven batteries.

(1) Open spraying and fogging: In contrast to systems which capture and scrub emissions, there are now systems, under careful study, that reduce the emissions at the source. As an example, a spraying system mounted on a hot car to create a partial water curtain that contains the emission. Water is

onto the hot coke, either in the guide as it emerges or in the hot coke car. The spray may be used to guide gas flows to cool coke and gas for the purpose of destroying convection effects and/or to wet and scrub out grit. These systems must contend with the rapid expansion of water that is converted into steam, and must be designed to avoid excessive ice formation during Winter operations. They must also provide for removal of entrained grit and dirt, whether or not the water in the system is recycled. However, this system does not appear, due to the haphazardness of the spraying, to be among the best at controlling the emissions.

(2) Bench mounted self-contained hoods: Integral hoods containing complete ventilating and scrubbing facilities are presently in use in various parts of the world. In one case the hood is mounted entirely on a bench car, and is cantilevered out over the hot coke car tracks. It is equipped with scrubbers, and fans, riding on the same vehicle as the hood. The collection of pushing emissions is reported to be only about 70% efficient. A second generation of this type of hood is now being installed in Germany. The hood is designed to cover the hot coke car throughout the push. It is also the only hood designed to use aspirations within the venturi scrubbing system itself for the primary draft. The boiler, to raise the required steam pressure for the venturi, rides on the bench behind a low secondary hood. The outreach of the hood itself is supported by an outside third rail over the cokewharf. The steam pressure is 8 atmospheres, and the total draft for the 8 scrubber exhausters is 70,000 cu.ft. per minute. A major feature of the system is that the draft and scrubbing system has no moving parts. The design of this system shows definite possibilities, and I feel should be pursued.

(3) Enclosures and hoods mounted on the hot car: There are several enclosed hot cars being developed and operated throughout the world today. One totally enclosed hot car operating in Germany operates in conjunction with an enclosed

coke guide and an underground quenching station, equipped for continuous quenching. The receiving hopper, which is not as long as a conventional hot coke car, discharges out of its bottom into a refractory line holding bin. During pushing, the coke guide and receiving hopper are locked together. When discharging, the hopper bottom is linked to the holding bin via a water trough seal. The enclosed hot car is exhausted by a combination of fan plus rotor vent scrubber rated at 8,750 cu. ft. per minute. During the push itself, a second system exhausts the coke guide at the rate of 5,250 cu. ft. per minute. Accordingly, the total draft at the peak emission rate is only 14,000 cu. ft. per minute, but in contrast to conventional hoods this system is enclosed so tightly that strong convection currents are not generated; thus, less draft is needed. It is reported that leakage and loss of draft occur where the guide meets the coke oven door jam, where the guide meets the hot car, and from the hot car. The overall effect is that some emissions of dust and grit are seen all through the pre-pushing, pushing, and coke transfer operations. The system is reported to contain and scrub perhaps 3/4 of the total potential pushing emissions. This is a first phase piece of equipment, and a modification to this system which was installed in Germany has now been installed in the United States. It is simpler in design and lower in profile than the German system. A two-part hood is mounted on the coke guide and one of the sections drops down to mate with a slanted opening in the top of the hot coke carrier. The carrier enclosure is a sliding lid of stainless steel screen, like that of a roll top desk. The carrier is exhausted via a rotary fan through a venturi scrubber, from the time the oven door

is removed until the carrier has been discharged into the receiver of the quenching system. This system is functioning far better than the original system installed in Germany. Because this system is designed to connect to a continuous special quenching system, which may extend some 40' to 60' underground, it may not be considered for use at all locations. The underground construction of the quench system might be difficult to stabilize at lakeside and tidewater sites, or other underground construction problems could occur. Another system is designed by partially hooding a standard hot coke car. The total system contains the hot coke car and hood, and a permanently attached trailer, holding the ductwork, pumps, controls, stack, and exhaust or draft system. The coke guide has a hood but is not exhausted, which allows pushing emissions to escape from this area.

(4) Moveable hoods with a fixed duct: This type of system is prevalent on most batteries in Japan, and is used on two batteries in the United States. It avoids the problem of carrying the fans, motors, and scrubbing equipment, on a moving vehicle. The duct handling the emissions is constructed the length of the battery, and is usually offset from the battery almost directly over the hot coke car, and about 1 meter above the battery top. The duct has specially designed ports located above each coke oven, that are opened and closed by connector mechanism attached to the door and coke guide machine. The hood is attached to, and moves with, the door and coke guide machine. One of the major drawbacks of this hood, is that it does not cover the total length of the hot car, and therefore, emissions can be given off into the outside atmosphere when the hot car emerges from underneath the hood. Two similar

systems have been installed in the United States. However, it is felt that these do not provide a sufficient control of emissions. The major reasons being, (a) the hoods covered only about $\frac{1}{4}$ to $\frac{1}{3}$ of the hot coke car, and were not offset, and, (b) preponderance of green coke or pushes overwhelmed the collection and control equipment.

(5) Coke side shed enclosures: Some three years ago, a shed covering the complete side of the coke oven battery was constructed in the United States, at the Great Lakes Carbon coke ovens in St. Louis. This enclosure is now being installed at several plants in the United States and Canada. It has, I feel, many advantages over the other equipment I have so far described. On the battery side of the ovens, the sheeting of this enclosure comes tightly against the coke oven battery, thus preventing any escape of emissions on that side. Away from the battery, the sheeting comes down within quite close limits of the ground, and can be varied to meet certain conditions. The advantages of the shed are, (i) the efficiency of both the capture and control of pushing emissions are maximised, (ii) the shed will capture emissions during a green push, (iii) the shed top can act as a surge tank for the emissions, thereby allowing the control device to receive a more uniform concentration. This will allow simpler and more efficient control equipment to be designed, than if large one minute surges of emissions must be controlled. In cases of modifications, it can be retrofitted to most existing batteries, with a minimum effect on production. And, finally, the shed will capture emissions from coke side coke oven door leaks. It is in this area that I feel the shed is unique. It is the first system which is capable of handling both sources of emission. While the emissions from coke side doors are

not large in volume, they can be very noxious, and even harmful to health. The principle upon which this shed works is that during the pushing of the oven a large volume of hot dirty air is generated. This volume can be anywhere from 400,000 to 1,000,000 cu. ft. By the configuration of the shed, the hot dirty air rises upwards into the holding chamber which is the top of the shed. The hot gases spread out laterally filling the total volume of this shed above what is virtually a low energy throat situated above the oven tops. This hot dirty air is held in this area, above this throat, by the venturi action of the throat, and can thus be evacuated over a long period of time in comparison to the time it takes to generate. This has the effect of reducing the size of any gas cleaning system which has to be installed with the equipment. Evacuation of the dirty gases generated during pushing takes place along the whole length of the shed through a tapered duct extending the total length of the shed. One of the great advantages of this piece of equipment is that there are absolutely no moving parts associated with it. This means, of course, that maintenance is reduced to an absolute minimum; a very important factor to be considered in operating any piece of equipment these days. This shed can be installed on any coke oven battery irrespective of size, either of oven or in the number of ovens making up the battery. As I said, one of these sheds has now been in operation for three years, and has been very successful. Five others are in various stages of construction, which are based entirely upon the concepts devised at Great Lakes Carbon Corp in St. Louis. There are also some three or four other sheds being installed which are modifications of the Great Lakes

system. Some of which are not quite as successful as the original shed. Industry, even though they have started a trend towards sheds, have expressed concern that the quality of the atmosphere within the shed may not meet regulations that exist in the United States for worker exposure to pollutants. Tests have been carried out under the auspices of the Occupational Safety and Health Administration to ascertain the quality of the environment underneath the shed. The findings of the two tests carried out so far have indicated that there is no significant difference to the exposure of workers to contaminants whether there be a shed installed on a coke oven battery, or whether it be an open coke oven bench. Incidentally, neither of these conditions need the requirements of OSHA. The control devices - being installed on these sheds - are of two types. The venturi scrubber, and the wet electrostatic precipitator. The selection of the piece of gas cleaning equipment depends basically upon the emission standards to be met, and here we come to a very great debating point, which will probably be ongoing for some considerable period of time throughout North America, if not the world. This point is: are condensible hydro carbons to be classed as particulate matter? In Ontario condensible hydro carbons are not classed as particulate matter. The only control on the emission of condensible hydro carbons, is that of opacity. In other words, the density of the smoke being given off from the stack of the gas cleaning system. If it is not necessary to control the emission of hydro carbons, either because there is no limit on hydro carbon emission, or because the opacity is not sufficient to be a violation, then a low energy venturi scrubber is capable of meeting the existing

codes. Low energy, meaning in the region of 10" to 18" pressure drop across the venturi itself. However, if it is necessary to control the hydro carbon emission, either because of regulations or because of opacity, then the best solution is the wet electrostatic precipitator. When I say best, this does not mean to say that a high energy venturi scrubber cannot achieve the same levels of emission control, however, in order to achieve these levels it would be necessary for the scrubber to have a pressure drop across the venturi in the region of 60" WG. When one combines this into a total pressure drop throughout the whole system, we have somewhere in the region of 72" on the fan. If one compares this to a total pressure drop through the system of 8" with a wet electrostatic precipitator, and if one considers an evacuation volume of about 200,000 cu. ft. per minute, it is easy to see that the precipitator, despite its higher capital cost, becomes a much cheaper piece of equipment over a fairly short operating period of time. At the moment, we have some five units now being installed throughout North America, and in each case we are designing on the basis of controlling and removing the hydro carbon emission. As with any wet system, of course, we do finish up by transferring our air pollution to a water pollution problem. We realised this some time ago, and are, of course, furnishing water treatment systems to go along with the shed and the gas cleaning equipment. While we feel that we have been successful in coming up with a reasonable answer to this major problem, there are many other problems to solve on a coke oven. There are the emissions generated during charging, and a tremendous amount of time, energy, and money, is being devoted by both the regulatory authorities and

the steel industry into methods of successfully controlling these emissions. Some success has been achieved, and I am sure that in time a complete answer will be arrived at. There is also the emission from the pusher side door, which is basically a coke oven door leakage problem. We are actively working on a solution to this problem also, by the use of a similar type hood, but on a much smaller scale. We do feel that we should have some reasonable solution to this problem in the not too distant future.

AIR POLLUTION CONTROL IN ONTARIO

THE PHILOSOPHY & MECHANISMS FOR AIR QUALITY MANAGEMENT

A brief statement of the historical development of air quality management in Ontario is given. The underlying rationale for managing air quality is one of effects. This concept treats air as a natural resource and aims at achieving a desirable air quality which is judged on the basis of the effect of contaminants on man, animals, vegetation and property in such a manner as to have no known adverse effects. This places constraints on the rate of contaminant emission from any source in the context of the geographical location of that source. The regulations define a maximum time concentration for any contaminant at the point of impingement, i.e., where the plume from the source intersects the ground, a building, or other significant object.

by

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AIR POLLUTION CONTROL IN ONTARIO - THE PHILOSOPHY AND
MECHANISMS FOR AIR QUALITY MANAGEMENT

by

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It may be of interest to begin by making a brief survey of the historical development of air quality management in Ontario. Although inception of air pollution control occurred in Ontario earlier than in most other provinces in Canada, the effective control legislation has been in effect a relatively short number of years. The first Ontario legislation referring to air pollution was contained in the pre-war Municipal Act, which was limited in scope to the control of smoke. It delegated the authority to control smoke emissions to municipalities, many of which proceeded to pass by-laws. The majority of such by-laws prohibited the emission of dense smoke, but did not define dense smoke nor state how it should be measured. However, most municipalities did not attempt to enforce their by-laws. This was the status in 1955 when the Ontario Government appointed a Committee to study air pollution and its control. As a result of this Committee's 1957 report, the Provincial Government passed the Air Pollution Control Act in 1958. This Act empowered municipalities to control all sources of air pollution. At the same time it provided for the entry of the Province in an advisory role.

In an effort to assist municipalities, the Act was amended in 1963, making the Province responsible for approving new industrial sources of air pollution. The results of these moves to stimulate activity at the Municipal level were disappointing. Only four municipalities employed full time staff to control air pollution and about a score more operated on a part time complaint basis. With this history it became apparent that if any progress was to be made in Ontario, in managing air pollution, the control function must be vested in one central agency. As a consequence, the Air Pollution Control Act, 1967, was passed, whereby the Province assumed

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the total control function. The enforcement agency set up was the Air Pollution Control Branch within the Ministry of Health. The Act was passed in June, 1967, proclaimed in October and became operational on January 2, 1968. The Branch was transferred initially to the Department of Energy and Resources Management and finally to the Ministry of the Environment as the Air Management Branch. The Act itself was superceded in August 1971 by the much broader in scope Environmental Protection Act, 1971. In the re-organization and decentralizing of the activities of the Ministry of the Environment in April, 1974, the Air Management Branch was eliminated and its functions distributed among a number of newly created Branches. In general, the control program functions were incorporated by the field forces in the regional offices, while the policy setting activities were retained by the headquarter's groups.

If ambient air quality did not affect health, or have an adverse effect on vegetation, or cause disagreeable odours, or dirty windows, it is unlikely that we would be concerned with passing control legislation. Since an effect is the reason for legislation, what pollutants go up a stack are of no consequence while they are in the stack - only after they are discharged into the medium of the ambient air.

The effects produced by a contaminant emission are the result of time of exposure and the concentration of the contaminant. These factors, in turn, are highly dependent on transport of the contaminant from the source to the receptor. Many government agencies use straight emission standards which indicate the maximum allowable rate of emission of the contaminant. However, these values are not easily translated into control of the effects of the emission. Some means of tying together the emission rate and the effects of the emission are necessary. In Ontario we have chosen micrometeorology and dispersion equations as a means of equating the effect at a point of impingement with a contaminant emission or plume from a source.

The micrometeorology aspect includes the influence of wind and convection currents in air caused by the heating of the earth's surface, upon the rise and dispersion of a plume from a stack. Wind speed will determine the travel time from a source to a receptor. It also has a dilution effect, since the concentration of a contaminant in a downwind location from a source is inversely proportional to the wind speed for many common meteorological conditions.

There are a number of dispersion equations that have been used in calculating contaminant concentrations at a point of impingement. The current ones used by the Ministry as described in the latest issue of O. Reg. 15, R.R.O. 1970 have been used for over 6 years and found very adequate in controlling ambient air quality.

The relationship between the quantity of a contaminant emitted from a single source is affected by the conditions at the point of emission including the quantity emitted - by the distance between the source and any point of impingement - by topographical features - by wind speed, and by thermal or mechanical turbulence in the air stream carrying the contaminant between the source and receptor.

To maintain acceptable air quality, it is necessary to control a contaminant at or below an effects level at any point as measured by concentration and time. The acceptable ambient air objective for a contaminant, as established by the Ministry, is based on the effect of that contaminant on humans, animals, vegetation and property (soiling, corrosion, etc.). Under normal circumstances the time period involved is 24 hours. At this point I feel it is desirable to stress the difference between the values established for the ambient air quality and the occupational health levels of a contaminant established in industry. In the case of industrial working conditions, we are concerned with exposure of healthy adults in the prime of life, exposed for a period of 8 hours a day and 5 days a week. In the case of the air quality in the community, we must consider exposure of the very young, the very old and the sickly for 24 hrs. a day, seven days a week. For this reason the 24-hour ambient air objective from a health standpoint, will be considerably lower than the equivalent occupational standard. Depending on the toxicity of the contaminant, the value can be between 1/10th and 1/200th of the occupational health figure.

The establishment of a 1/2 hour standard for a contaminant emission from a single source is a judgement process, taking into consideration, in most cases, the 24-hour ambient air objective, the time factor differential, and the possibility of other sources of the same contaminant in the area as well. In some cases, short terms factors must be used as a basis, such as odour threshold level. Thus the value set as the 1/2 hr. standard for a contaminant emitted from a single source will be aimed at having all sources of a contaminant in an area jointly meet the ambient air objective over any time period and at any point of impingement.

By making the 1/2 hr. ave. standard apply at the receptor location, rather than at the point of emission, this approach reflects the basic philosophy that the compelling reason for air quality management is effect. Thus, by their nature, these standards, tailored to a specific location by the point of impingement mechanism, control ambient air locally, and in a general way, reflect multi-source or area situations.

The standards are used by the Ministry to assess incoming applications covering either new sources of emission or modifications of existing ones. They are used by the Ministry field personnel for assessment and abatement of existing situations. When any source of emission gives rise to a concentration of a contaminant at a receptor, which exceeds the standard, the situation can be corrected by altering the conditions under which it is emitted. The choice made will be dependent on the extent to which the calculated concentration at the point of impingement exceeds the standard and by the economics of the situation. If the standard is exceeded by a factor of less than two, it may be desirable to increase the stack height. If the standard is exceeded by a factor of more than two, it is rarely practicable to increase stack height, and normally control equipment will be necessary to reduce the quantity of contaminant emitted. In this regard, therefore, the point of impingement standard can be considered an emission standard as well.

The degree of control necessary to meet a point of impingement standard for a contaminant will be sensitive to location. From our viewpoint a heavy concentration of industry in one area is not a desirable situation. However, if a firm insists on moving into such an area, it must pay the price in the form of higher cost for high efficiency control equipment.

Since we are subject to the vagaries of weather and the assumptions made in establishing standards are not necessarily accurate, it is desirable to have other enforcement tools at the disposal of Ministry personnel for controlling ambient air quality. One such approach is known as the Director's Order, which is a course of action dealing with a specific emitter and is based on a detailed examination of the emissions from that source and their effects, known as the Section 83 survey. These Orders are used by Regional Directors to achieve satisfactory abatement of specific sources in an existing situation. They are also used to control emergency situations by the issuance of a Stop Order or Control Order. The advantage of the Director's Order is that it can lead to prompt abatement of existing sources, since it can be tailored to specific situations in respect to both local circumstance and time. Generally the Director's Order requires emission reduction to meet a published standard. However, it may contain requirements beyond those which follow from the standards - specifically housekeeping, or where warranted, source control requirements tighter than those inherent in the standards list in O. Reg. 15. The Director's Order also allows a degree of flexibility in the general application of standards with respect to timing.

A third approach to control by the Ministry is the use of Regulations. Under the existing Act, authority is granted for the passing of regulations covering a wide variety of situations, among them being -

1. General situations - such as smoke emissions, incineration and the Air Pollution Index as outlined in O. Reg. 15, R.R.O. 1970.

2. Specific industries - asphalt plants covered by O. Reg. 183/72
or ferrous foundries under O. Reg. 11,
R.R.O. 1970

3. Specific situations - such as the sulphur content of fuels used
in Metropolitan Toronto, O. Reg. 17,
R.R.O. 1970.

Regulations are used by the Regional Directors to obtain abatement action on existing sources, and by the Environmental Approvals Branch to control potential emissions from new or modified sources. They allow uniformity of policy application throughout an industry. In the case of the Air Pollution Index, currently administered under Section 4 of O. Reg. 15, the emissions are curtailed on the basis of ambient air measurement along with a meteorological forecast.

The final control mechanism available under the Environmental Protection Act, 1971, is the use of guidelines. These are published documents outlining Ministry administrative policies with respect to a wide variety of matters for which it is deemed inadvisable to publish formal regulations or impracticable to use any of the other enforcement tools under the Act.

Published guidelines by their nature, are apparent regulations which are not legal requirements. However, a guideline used in the assessment of an application for Certificate of Approval is considered enforceable if challenged, though invariably moral suasion is sufficient to obtain acceptance. They can be in the form of emission guidelines dealing with area situations where there is competition for air space with respect to common contaminants due to a large number of strong sources located closely together (e.g. sulphur dioxide concentrations in the Sarnia area). A more general form of guideline concerning SO₂ emissions was also produced to assist Ontario Hydro in siting new thermal generating stations or expanding existing facilities in the province. Here the problem is one of ensuring that a very large single source in an area does not take up too much air space.

A common use of guidelines is in connection with control equipment requirements. Examples include the Criteria for Incinerator Design and Operation for 3-chambered incinerators, or the guidelines for buffer zone distance for siting pit incinerators or sewage lagoons, or the establishment of a table of recommended minimum reaction temperatures and retention times for complete incineration of a variety of waste products.

Guidelines have also been used in the evaluation of asphalt plant emissions by establishing wet scrubber efficiencies for a variety of scrubber designs to ensure consistency of assessment.

Turning now to the latest regulations issued under the Environmental Protection Act, it should be pointed out that the changes made are not new in a functional sense, and are really formalizing matters which had been in force for some time. Specifically the new regulations stipulate the method of calculation for a point of impingement concentration and also publicize ambient air objectives and standards which have been in use for a number of years, although they had not yet been published in previous regulations.

Fuel burning equipment for comfort heating in a building using natural gas or No. 2 fuel oil at a rate of less than 1.5 MM BTU/hr is exempt from applying for a Certificate of Approval. The exemption was introduced in view of the fact that from experience, pollution problems at these heat loads and with these fuels are not encountered. On the other hand, equipment for the preparation of food in restaurants and quick food outlets now require a Certificate of Approval for their installation and operation as the result of the periodic complaints received by the Ministry concerning some of these establishments.

In assessing visible emissions from stacks, the concept of plume opacity has been introduced as a means of assessing multi colored plumes from industrial operations. In the past, based on a Smoke Density Chart, only plumes from combustion sources could be assessed for compliance with the allowable smoke density.

With regard to incinerator performance, the regulations now establish acceptable combustion efficiency by measurement of the hydrocarbon content of the outlet flue gas. The equivalent methane concentration in the flue gas must not be higher than 50 ppm by volume.

In the Appendix we have formalized the methods for calculating contaminant concentrations at a point of impingement. These methods have been used within the Ministry for years in assessing incoming applications. Now, these methods have been made mandatory for evaluating contaminant emissions for compliance with the regulations or standards.

The simplest approach to calculating contaminant concentrations is based on the Scorer and Barrett formula, which is a mathematical derivation based on the assumption that an emission from a stack will take the shape of a cone, with the contaminant uniformly distributed. It is basically limited to points of impingement located on the same building as the point of emission.

If you have ever driven a convertible with the top down and found your hair blowing forward in the same direction as the motion of the car, you will have experienced the principle upon which the virtual source method of calculation in (b) section of the Appendix has been based. A wind blowing over a building tends to form an eddy on the downwind side of the building, in which the air swirls around in a generally circular direction. Any contaminant emitted by a low stack on the building will tend to accumulate in this pocket or building envelope as it is usually called. This method of calculating assumes that the emission is originating from a stack some distance upwind from the building upon which the point of emission is located. The axes of the imaginary plume will be dependent on the geometry and size of the building itself. The sketches included with O. Reg. 15, indicate the situations under which this method of calculation would apply.

In subsection "c" we have the classic case of contaminant dispersion for conventional dispersion of a plume from a stack using the Holland plume rise and the Pasquill-Gifford equation for calculating the contaminant concentration at a point of impingement. In this situation the stack is high enough to clear the building envelope and any possible aerodynamic interference from any nearby high-rise building.

As mentioned earlier, one factor taken into consideration in calculating dispersion by either the (b) or (c) method, is the vertical movement of air due to temperature changes due to the warming of the ground. This vertical movement of air can be very rapid or non existent, as in the case of inversions and is classified into a number of grades from A to F, going from one extreme to another. Under neutral stability also known as D, the air temperature drops at the rate of approximately 1°C for each 100 metres of height. C stability is somewhat less stable, therefore the temperature change is somewhat greater. Since C or D stabilities occur in this province most of the time, these are normally the stabilities upon which the dispersion calculations are based when assessing a contaminant emission. In the case of a very large source it may be necessary to also consider the less frequency stability conditions, due to the possible impact of this emission over an extended area.

It may be of general interest to indicate the present procedure used by the Ministry in establishing an ambient air criterion or objective and standard for a new air contaminant. As mentioned earlier, the governing factor in establishing an acceptable level of contaminant in the atmosphere is effect, and in determining the standard we investigate the effect of the contaminant in four main areas of concern - human health, vegetation, effect on animals and finally the effect on property of the physical characteristics of the contaminant, such as corrosion, soiling or staining.

A request for a new standard will usually originate from the Environmental Approvals Branch or the regional offices of the Ministry, although it can originate from a wide variety of sources. The approach to standard setting involves a committee including representatives from other branches of the Ministry of the Environment, and the Ministry of Health. If necessary, experts in that specific field, both inside and outside the Ministry are contacted. If the contaminant involved is a hazardous one, the preliminary work may involve ambient air surveys in the vicinity of industrial plants emitting the contaminant, and the development of methods of analysis. The main purpose being to establish an ambient air objective upon which a standard could be based.

Periodically an air contaminant is encountered about which there is inadequate knowledge available to allow the setting of a firm standard. In this situation a temporary guideline is established, on the basis of the data that is available, indicating the maximum allowable concentration for a 1/2 hr. average. Approval of any application involving the emission of this contaminant would be conditional, subject to re-assessment when sufficient information becomes available to allow the establishment of a firm ambient air criterion and standard.

DEVELOPMENT AND IMPLEMENTATION OF
FEDERAL ENVIRONMENTAL PROTECTION REQUIREMENTS
IN ONTARIO

The government-industry task force technique for defining "best practicable technology" for pollution control from various industrial sectors is described. The differences between regulations, standards, guidelines and codes of good practice are discussed. Programmes for implementing these requirements are developed to ensure minimal duplication and conflict with other levels of government.

Environment Canada's responsibilities for environment protection with respect to the activities and facilities of the Federal Government are described. The relationship between the well established clean-up programme for the Federal Government's own facilities and the more recent environmental assessment process is given.

by

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DEVELOPMENT AND IMPLEMENTATION OF FEDERAL ENVIRONMENTAL
PROTECTION REQUIREMENTS IN ONTARIO

by

Dr. Robert W. Slater

Responsibilities for environmental protection were not assigned in the constitutional division of powers between the federal and provincial governments. The legislators who framed the British North America Act in 1867 did not foresee the future magnitude of these present-day concerns. The Parliament of Canada was given certain powers relating to coastal and inland fisheries, transport, trade, taxation and criminal law (which has been interpreted to include environmental matters national in scope). The provincial governments, on the other hand, have been given the authority to regulate the use of most natural resources within the provincial boundaries including land, water, minerals, timber, wildlife and, to an extent, air space. Other matters of property and civil rights are also a provincial responsibility.

Effective response to the challenge of environmental protection depends not simply on a fixed jurisdictional framework, but on flexible cooperation between the federal and provincial governments working together in pursuit of common objectives on programs of joint interest.

This paper describes the methods which have been adopted by Environment Canada for developing national environmental protection requirements and the procedures employed to implement those requirements within the Province of Ontario. Programs affecting the industrial sector, other federal government departments and agencies, as well as areas of special interest such as the Great Lakes, are covered. It is important to recognize that the procedures adopted for implementation are specific to the Province of Ontario. Procedures developed in other provinces will reflect local conditions, including the extent to which responsibility for administration of federal legislation has been delegated to the Province, as well as the particular characteristics of the provincial regulatory agencies.

ENVIRONMENT CANADA'S ROLE

When Environment Canada was formed in 1971 the federal government brought within one organization the federal responsibility for renewable resources management and utilization in the fields of fisheries, forestry, wildlife, water, land and the atmosphere. In addition a new element was created, the Environmental Protection Service, with particular responsibilities for environmental protection -- particular emphasis upon meeting the needs for proper utilization and management of the renewable resources.

THE ENVIRONMENTAL PROTECTION PROGRAM

The Environmental Protection Programs that were developed by Environment Canada, recognized both short and long term, as well as national and local needs .

- I. We have instituted a program for developing minimum national standards for the control of discharges into both air and water . These minimum requirements are developed with the objective of containing pollutants at source as opposed to relying upon the dispersive capacity of the environment. They also provide for a degree of equity between similar operations located in different parts of the country. In this regard these minimum national requirements may be considered as conceptually similar to national construction or health and safety codes.
- II. While the implementation of national minimum requirements will be effective in removing instances of gross pollution, this will not meet the needs of the environment in all locations. As a consequence, more stringent environmental protection safeguards may be necessary in particular areas to afford comprehensive protection of all components of the environment.

It is considered that these basic principles of environmental protection are pertinent to both the private and the public sector. They are applicable to industrial and municipal sources and are also incorporated into programs for both the clean-up and prevention of pollution problems from facilities of the federal government. In the latter case an objective of meeting exemplary standards in environmental protection has been set.

INDUSTRIAL PROGRAMS

- I. Legislative Authority - There are three primary pieces of legislation which are used by EPS for pollution control at source. These are:

The Fisheries Act

The Fisheries Act was a law in effect at the time of Confederation. While the primary focus of the Act was on management of the commercial fishery, Section 33, referred to as the general provisions of the Act, make it an offence to discharge any material into waters frequented by fish which are considered deleterious to fish. The Act was amended in 1970 and Sections 33 (4) and 33 (12) provide additional powers to set regulations prescribing conditions under which the deposit of a waste may be authorized.

The Clean Air Act

The Clean Air Act became law in 1971. A number of sections of this Act are used for the purpose of establishing regulations and guidelines. Section 7 of the Clean Air Act allows for the prescription of national emission standards for air contaminants from stationary sources that constitute a significant danger to the health of persons, or would likely result in the violation of any international obligation.

Section 8 allows for the prescription of national emission guidelines for any source, stationary or otherwise.

Section 22 allows for the prescription of regulations to limit fuel additives. There have been regulations prescribed for limits of lead in leaded and non-leaded gasolines. These are set at 3.5 gPb/gal. effective January 1, 1976 and 0.06 gPb/gal. effective in 1974, respectively.

Canada Water Act

Section 18 of the Canada Water Act has been used to establish maximum permissible concentrations of phosphorous in detergents. As of January 1, 1973 the maximum permissible concentration in detergents was 5% by weight expressed as phosphorous pentoxide.

There are, in addition, numerous other pieces of federal legislation which are administered by other departments through which significant advances in environmental protection have been made. Some examples in this category include:

The Motor Vehicle Safety Act - which establishes emission rates for vehicles either manufactured or imported into the country.

The Canada Shipping Act - for the control of pollution from marine sources.

The Navigable Waters Protection Act - which relates to all filling or modifications of navigable waters including wharf and harbour construction, filling, pipeline crossings, etc.

In addition, the recent passage of the Ocean Dumping Act will provide extra controls in coastal provinces for materials disposed at sea. Finally, the Environmental Contaminants Act, currently in committee, heralds a new era of environmental legislation as it provides the ability to regulate the introduction, use, distribution and processing of materials. The whole thrust of this new legislation is preventative.

II. Regulations and Guidelines

Utilizing the authority of the legislation, the Environmental Protection Service issues both regulations and guidelines for various aspects of environmental protection. It is important that the distinction between these two be clearly understood.

The Random House Dictionary of the English language gives the following definitions:

Regulation: A rule or order prescribed by authority, as to regulate conduct; a governing direction or law.

Guideline: Any guide or indication of a future course of action: the government laid down the guidelines on its future policy in the United Nations yesterday.

Statutes and Regulations

Statutes are laws which are passed by the Parliament of Canada or a provincial legislature. Frequently, a statute will contain a provision stating that the Governor in Council (or the Lieutenant Governor in Council in the case of a province) may make certain kinds of regulations. In practical terms this means that Parliament (or the legislature) has delegated authority to the cabinet, on the recommendation of the appropriate minister, to make regulations on certain subject matter that has been specified in the statute. Once a regulation is made it has the same legal effect as if it were part of the original statute that Parliament (or a legislature) passed. A regulation is a specific law that legally applies in all relevant situations. A government agency does not have authority to exempt anyone from the legal obligation to obey a regulation, although there may be circumstances where a government agency may exercise discretion and choose not to prosecute a person for breaching a regulation under particular circumstances. The Crown does have the right to decide whether it will proceed with any particular prosecution.

Guidelines

In contrast, a guideline is not a specific law as is a statute or a regulation. Guidelines may also be referred to as standards of practice, codes of practice, objectives or explanatory notes depending on what terminology happened to be chosen.

The word guideline does not have an exact legal meaning as do the words statute or regulation. A guideline is commonly a statement by a government agency which indicates what practices will be considered by the agency to be in compliance with the intent of the law. Other guidelines may explain the interpretation that a government agency has placed on certain statutes or regulations. Such guidelines are not law, and a court would look at the specific words of the statute or the regulation itself when faced with interpreting the law.

The fact that a person is not following a guideline does not automatically mean that he is violating a law. It is possible that he is violating a law, but in a prosecution, the crown would have to prove that he was violating the law itself. It would not be sufficient just to prove that he was not complying with the guideline.

Guidelines may be regarded as an expression by a government agency of what the agency considers compliance within the spirit of the law. Since a guideline is not a law itself, a government agency can make exceptions to the general rule in circumstances where it considers it appropriate. A guideline permits flexibility and the exercise of discretion.

III. Procedures for Developing Regulations and Guidelines

National effluent and emission regulations and guidelines are being developed on an industry sector basis. Table I provides information on the current status of this program.

The procedures which have been adopted are similar for all aspects of this program. We extend invitations to provincial agencies and representatives of the industrial sector to work with us in drafting a technical expression of the "best practicable technology" for pollution abatement as it applies to that industrial sector. The best practicable technology is based upon a "state-of-the-art review" of current practice. It is considered as a standard of pollution abatement which should be attainable by a viable member of that sector and should be considered a minimal level of expectation for a new facility, as well as an attainable objective for existing industry within a negotiated schedule of compliance. An exception to the "best practicable technology" approach is taken when writing regulations under Section 7 of the Clean Air Act for substances considered a significant threat to human health. For these contaminants, the most stringent standards attainable are demanded.

Throughout this program, considerable emphasis is placed upon consultation between the federal and provincial governments, as well as industrial representatives. We remain convinced that by soliciting expertise from all available sources, we will not only produce a better product, but that we will also minimize the adversary role that can develop between government and industry, frequently to the detriment of both parties. We would like to acknowledge the substantial and valued contribution that the Ontario Ministry of the Environment has provided us in this development program.

IV. Implementation

Water Pollution Control

Fisheries Act Regulations are mandatory minimum requirements for new plants or substantially modified and expanded facilities, as defined in the Regulations. The provinces are encouraged to adopt more stringent requirements in order to meet the needs of the local environment using the provisions of their own legislation.

In the case of guidelines, we encourage the provincial agencies to adopt our guidelines as statements of best practicable technology for existing facilities and to incorporate both the principles and numerical values into compliance schedules or environmental protection orders issued by those agencies. In the event that an existing operation was causing problems with respect to the viability of the Fisheries resource, then it would be possible to invoke the general provisions of the Fisheries Act, to require a specific clean up program.

Air Pollution Control

Regulations developed to limit the discharge of substances considered to be significant hazards to health are mandatory requirements for all operations -- both new and old -- a date at which such regulations become effective is contained in the Regulation.

In the case of guidelines, we encourage the provincial agencies to adopt the principles and numerical values contained in the guidelines as statements of best practicable technology for pollution abatement at existing facilities. We also wish to ensure that air quality objectives which have been promulgated under the Clean Air Act are met. A long-term objective is to see those levels specified as the maximum acceptable level of air quality attained by 1980.

Both the federal and provincial government recognize the necessity for minimizing unnecessary duplication and potential conflicts in implementing the pollution abatement requirements of both jurisdictions. Accordingly, administrative arrangements have been developed which embody the following principles.

- (a) The province agrees to establish and enforce requirements at least as stringent as the agreed national baseline requirements. Such requirements would be applied at start-up for all new installations or for installations undergoing major plant modifications. In all other cases the national baseline requirements would be applied as a minimum as rapidly as possible to meet agreed objectives and time schedules.
- (b) Canada and the Province agree to appoint officers designated by either governments to facilitate inspection for compliance with national effluent and emission requirements. Appropriate arrangements for either federal or provincial inspection of federal facilities would be determined by specific agreements.
- (c) Canada will agree to take direct enforcement action -
 - (i) at the request of the province, or
 - (ii) where the province cannot, or for some reason fails to, fulfill its obligation with respect to matters of federal jurisdiction administered by the Province.

These principles covering complementary pollution abatement programs, as well as the subjects of criteria development and data and information exchange between the two governments, are being covered by an Accord which is being developed by the two governments. It is hoped that negotiations on the detailed wording will be finished this Fall and that these Accords will be signed by our respective Ministers. The initiative for this was developed with the Province of Ontario and has now been extended to the other provinces. It will endorse, and in certain instances expand upon, the effective cooperation which has been developed by departmental officials.

SPECIAL AGREEMENTS

I. Federal/Provincial

While a great deal of effective cooperation in the field of environmental protection between the provincial and federal level of government may be effected through the development of appropriate working relationships, there are certain activities of both governments that are only capable of being properly considered within the context of a formal agreement. The most comprehensive of those in existence, at the present time is the Canada/Ontario Great Lakes Water Quality Agreement. This agreement was signed in 1971, and preceded by approximately one year the International Agreement on Great Lakes Water Quality. The Canada/Ontario Agreement is complementary to the International Agreement and was effective in demonstrating to the United States the high priority and importance that both Canada and Ontario attached to the protection and enhancement of water quality in the Great Lakes Basin. Under the Agreement, Canada and Ontario agreed to two major programs:

- a) Canada, through the CMHC sewage loan program, would agree to provide, originally 167 million dollars, subsequently amended to 209 million dollars, to support financing of municipal sewage treatment plants and trunk sewerage systems in the lower Great Lakes Basin. It was also agreed that this would include the installation of phosphorous removal facilities to ensure that net phosphorous loadings from municipal sources would be in accordance with the limits set by the Canada/U.S. Agreement on Great Lakes Water Quality.
- b) A jointly funded 6 million dollar research program would be undertaken in order to provide solutions to the problems associated with the abatement of pollution from municipal sources, with particular emphasis on phosphorous removal technology.

In all substantive aspects, performance under the Canada/Ontario Agreement has been a resounding success. Ninetyeight per-cent of the sewered population in the lower Great Lakes is in compliance with the water quality objectives prescribed under the Great Lakes Agreement and, with a few very minor exceptions, phosphorous removal facilities are installed and operational at sewage treatment plants. The joint research program enabled treatability studies to be conducted prior to the installation of phosphorous removal facilities and continues to support key work in the areas of the disposal of sewage sludge on land as well as the development of techniques for comprehensive urban drainage management.

I would like to bring some recent developments in this area to your attention. Firstly, we are currently negotiating an amendment to the Canada/Ontario Agreement to permit it to continue after its current expiry date of December 31, 1975. Obviously those programs that were initiated under the Agreement, and which have met their objectives will not be renewed. However, there are many aspects of the International Agreement on Great Lakes Water Quality which obligate the federal government to certain actions which are more properly the responsibility of the provincial government. Our proposal, as it currently stands, is to recognize those aspects in the amended agreement. There is also the possibility that certain of the research investigations which have, by their very nature, a long-term component in them, may also be continued.

The second item of significance is related to the amendments to Part VIII of the National Housing Act respecting the provision of federal funds to finance municipal sewerage works. Briefly the amendments include:

1. Elimination of the time limit to qualify for 25% loan forgiveness.
2. Grants on a per capita basis available in addition to 25% forgiveness -- directed at small municipalities.
3. Loans available for trunk storm sewers to April 1, 1980.
4. Grants equalling 25% forgiveness available to provinces and municipalities who use other funding source.
5. Grants, available to develop comprehensive regional sewerage collection plans.
6. Broader definition of sewage treatment projects to allow incorporation of new technology.
7. Provincial/CMHC agreements as prerequisite to and framework for, funding projects in a province.

It is expected that these changes in the financing of sewerage works will allow for the further abatement of pollution from municipal sources.

II International

The federal government has the prime responsibility when it comes to dealing with environmental matters at an international level. In the majority of instances, however, either the source or the receptor is within provincial jurisdiction. In practice, this means that there must be an effective working relationship between both levels of government to ensure that the problem is properly identified and solved. The fact of substantial transboundary waters and high concentrations of population and industrial activity on both sides of the border mean that within the province of Ontario, procedures for dealing with matters of international concern have reached a high degree of sophistication.

In certain instances, matters of concern to both the United States and Canadian government will be discussed on a bilateral basis by the parties. On other occasions, the matter may be referred to the International Joint Commission for the preparation of recommendations leading to its solution. At this conference last year, you received a detailed description of the procedures which have been adopted by the International Joint Commission to ensure that the requirements under the Great Lakes Water Quality Agreement are met. Both Environment Canada, other federal agencies, as well as a number of provincial agencies, primary amongst which is the Ontario Ministry of the Environment, have allocated substantial resources to this activity.

Achievement to date is encouraging according to the latest report of the IJC Great Lakes Water Quality Board, a board specifically established to oversee the implementation of the Agreement. Some of the accomplishments include the development and implementation of a joint contingency plan for spills of oil and other hazardous polluting substances; the continuing effective reduction of phosphorous inputs into the lakes to decrease eutrophication through implementation of regulations in detergent production and of phosphorous removal facilities in sewage treatment plants; the development and implementation of an effective surveillance and monitoring program (of lake waters) under the aegis of the IJC; the increased capability to identify industrial point source polluters and to monitor their compliance efforts; and the development of a list of hazardous polluting substances to be controlled. The Agreement constitutes an experiment in international resource management and although we are encouraged by the degree of government cooperation so far effected in developing compatible or joint control programs, we are still very much aware of the tasks required to preserve the Great Lakes.

ACTIVITIES AND FACILITIES OF THE FEDERAL GOVERNMENT

One role of Environment Canada is to act as the environmental conscience of the federal government, particularly as it relates to the activities and facilities of its own departments and agencies. There are two aspects to this-- clean up of existing problems, and prevention of future ones.

(I) Clean-up Program

In June, 1972, Cabinet decided to establish a program to provide funds for existing departments to clean up pollution problems. The responsibility for administering this program was given to the Environmental Protection Service. The program is available to all departments of the federal government, but is not available for crown corporations.

In F/Y 1974/5, a total of 12 million dollars was allocated on a national basis. This provided funds for both the design and construction of pollution control facilities at federal establishments and was allocated to the abatement of air, and water pollution and the handling of solid and hazardous wastes. The allocation in the province of Ontario was approximately 2 million dollars in that period. Estimates for the current fiscal year, which finishes on March 31, 1976, is approximately 2.5 million dollars. This will be distributed over some 50 projects, and will range from fuel conversion, to the installation of nutrient removal facilities at water pollution control plants. The objective of the program is that the federal government should demonstrate an exemplary standard of environmental protection at its own facilities.

Some examples of projects completed in F/Y 1974/5 are as follows:

a) Canadian Forces Base, Borden
Solid Waste Management Program

A comprehensive evaluation of the solid waste problem at C. F. B. Borden was undertaken. In addition to the usual garbage volumes, classifications and projected landfill capacities, the study investigated the broad environmental effects of landfill on the area. The latter aspect of the study consists of two parts. Firstly, the existing land fill site was closed down and monitoring stations were set up to measure any contamination of surface

and ground waters in the immediate vicinity of the site. The second part of the study concerned the opening of a new site, with all aspects of the landfill carefully monitored from the very beginning. In addition to recommending a specific area where landfill could be safely undertaken, the study recommended proper closing procedures for the existing site. The experience gained from this project will be used to develop solid waste management guidelines effective for all facilities of the federal government.

b) Toronto International Airport

We will soon complete an investigation of environmental problems associated with the Toronto International Airport. This is primarily a stationary-source oriented study directed at air emissions, fuel spills, runoff, industrial waste and solid waste. One of the major recommendations already developed from the study will be for the addition of an on-site incinerator to dispose of all international solid waste.

c) Vessel Waste Program

By the end of the summer, most of the federally owned vessels operating on the Great Lakes will be fitted with sewage holding tanks. This is in keeping with the federal policy of "no discharge" for federally owned and operated vessels. Presently there are five locations with adequate pump-out facilities, and additional sites are scheduled for installation this year, with completion in 1976.

II. Prevention

In order to ensure that appropriate environmental consideration are incorporated into the new facilities and activities of the federal government, a number of actions have been taken.

- (a) Environmental Assessment - sometimes simply meeting air and water pollution control standards is not sufficient to adequately protect the environment. This was recognized when the Environmental Assessment and Review Process was instituted.

The purpose of the process is to ensure that departments and agencies of the federal government will

take environmental matters into account throughout the planning and implementation of projects, programs and activities. A project will be a candidate for the environmental assessment and review process in the event that it meets one or more of the following criteria:

- i. it results from a federal initiative;
- ii. it involves federal land;
- iii. federal money is involved.

At the present time, the procedures which are in place include the following:

- i. it is the responsibility of the initiating department or agency to request that an environmental assessment be undertaken.
- ii. a panel is constituted and issues terms of reference for the environmental assessment to be undertaken by the proponent department.
- iii. the panel receives and undertakes a review of the study report and develops recommendations to the Minister of the Environment.

Effective data exchange occurs between Environment Canada and the Ontario Ministry of the Environment and Natural Resources on possible environmental effects of proposed major developments. Procedures are in place to ensure that there is minimal duplication and conflict between the jurisdictions in carrying out environmental assessments.

The federal process has been in place for slightly over a year. To date, one project has gone through the complete process. This was the Point Lepreau Nuclear Power Plant in New Brunswick. There are, however, other projects across the country which are in various stages of consideration by assessment panels. In Ontario, the proposed Steam Generation Plant for the National Capital Commission is included.

- (b) Environment Design - once a project has been authorized, then it will be necessary to proceed to a more detailed phase of design. At this point it will be necessary to ensure that all regulations or guidelines are adhered to, as well as any special requirements in order to meet local conditions. This process of designing in the good, and designing out the bad has been termed the environmental design phase.

An example of this is provided by our involvement in the New Toronto International Airport to be located at Pickering. There we have issued guidelines to the Ministry of Transport providing them with environmental direction for the design, construction and operation of the facility.

In this paper I have highlighted some of the key environmental protection programs that have been developed and implemented by the federal and provincial governments working as a team. I have attempted to demonstrate that both governments have placed high priority on properly defining problems and implementing solutions, rather than a concern over jurisdictional demarcation lines. We believe that the people of Ontario and of Canada will benefit from this approach.

TABLE I

SCHEDULE FOR REGULATIONS/GUIDELINE DEVELOPMENT

	<u>FISHERIES ACT</u>		<u>CLEAN AIR ACT</u>	
Completed:	Phosphorus in Detergents	1970, revised 1972	Cement	October 1974
	Pulp and Paper	1971	Asphalt	Summer 1975
	Chlor Alkali Mercury	1972	Coke Oven	Spring 1975
	Petroleum Refining	1973		
	Fish Processing Guidelines	1975		
Current:	Base Metal Mining & Milling	1976	Secondary Lead	Fall 1975
	Pulp and Paper (Revision)	1976	Arctic Mining	Fall 1975
	Alkali & Associated Products	1976	Natural Gas Processing	Fall 1975
	Potato Processing	1976	Incinerators	Winter 1975-76
	Textiles	1976	Meat Products (Code of Good Practice)	Fall 1975
	Organic Chemicals	1976	Asbestos	Winter 1976-77
	Metal Plating	1976	Thermal Power	Summer 1976
	Meat Products	1976	Petroleum Refineries	Winter 1976-77
			Chlor Alkali	Spring 1976
	Base and Precious Metal Smelting and Refining	1976	Iron and Steel	Winter 1976
	Recycling and Rerefining (Waste Oil)	1977 or 1978	Ferrous Foundries	Fall 1976
	Iron and Steel	1976	Pulp and Paper	Summer 1976
	Bulk Terminals	1977	Non Ferrous Smelters	Winter 1976-77
	Pleasure Craft (Vessel)	1977	Petrochemicals	Spring 1977
	Model Sewer Use By-law	1977	Ferroalloys	Spring 1977
	Vessel Sewage	1977	Fertilizer	Summer 1977
	Coal	1977		
	Fertilizer	1977		
	Dairy	1977		
	Miscellaneous Wood	1978		
	Commercial Vessel Discharge	1978		
	Exploration & Production of Petroleum	1978		

ANTICIPATED ACTIVITIES FOR REGULATION GUIDELINE DEVELOPMENT BEYOND 1978

UNDER THE FISHERIES ACT

Acids and Associated Products
Oil Sands Development
Brewing and Distilling
Fruit and Vegetable Processing
Industrial Minerals
Municipal Stormwater Discharges
Ceramics
Glass
Oils, Fats, Waxes
Rubber
Tanneries
Explosives
Grain Milling
Wineries and Miscellaneous Food
Coal Gasification

AIR ENVIRONMENT REVIEW OF ASBESTOS, MERCURY AND LEAD

The potential health hazards of airborne asbestos, mercury and lead have been of increasing concern because of the possible long term deleterious effects of exposure to low concentrations of these materials. Existing ambient concentration measurements are provided for geographical areas of recent concern. As background the flow of these materials through the Canadian economy and details of the various physical and chemical forms and uses are discussed. Estimates are presented of emitted quantities by geographical area and source and include mining, manufacturing, waste disposal and inadvertent releases.

The pathways by which the materials find their way into the environment are described and quantities are provided for controlled, uncontrolled and inadvertent sources as determined from surveys, actual measurements and recent investigations in Ontario.

Presented by



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AIR ENVIRONMENT REVIEW OF ASBESTOS,
MERCURY AND LEAD

by

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INTRODUCTION

Airborne asbestos, mercury and lead have been of increasing concern as a result of the potential long term hazards associated with exposure to low concentrations of these materials in the environment.

As a first step in discovering the extent and severity of such a problem, it is necessary to identify potentially significant sources. An inventory, which considered the flow of asbestos, mercury and lead through the Canadian economy, and examined potential sources and potential pathways by which these materials find their way into the air environment, was performed for the base year of 1970. These inventories are described in more detail later in this paper.

In order to quantify the potentially critical areas identified during the inventory process, it is necessary to perform further studies which might include close examination of: the processes involved, the con-

trol equipment used, stack testing, measurements of ambient air quality and mathematical modeling of atmospheric dispersion. Once these tasks have been undertaken in a serious and logical sequence, then practical recommendations for the control of significant sources can be made.

As an illustration of one of these techniques, results of recent stack test measurements are discussed later in this paper.

In 1972, James F. MacLaren Limited undertook a study for the Air Pollution Control Directorate to perform an inventory of sources and emissions of atmospheric beryllium, asbestos, mercury and lead. The inventories were based on the sources of emissions for the year 1970, since, at the time of the study, complete data was not available for more recent years. Certain of the following information is abstracted from these reports.

ASBESTOS - SOURCES AND EMISSIONS

Asbestos is the name given to a group of approximately thirty hydrosilicate materials. Asbestos, with its fibrous physical structure, combined with such properties as non-flammability, good flexing properties, high tensile strength, good heat and electrical insulating ability and good resistance to acids and alkalies, has

become one of the world's most useful industrial materials.

The world consumption of asbestos is concentrated in seven main areas. The most significant of these is its use as a binding agent wherein the dispersal of tiny asbestos reinforcing rods through a material gives that material increased strength and durability. The seven most important applications of asbestos are in asbestos cement, floor files, asbestos paper, friction materials, paints, textiles and plastics.

The health effects of asbestos exposure will be discussed in the next talk, although it should be noted that different forms of asbestos have different effects on health.

Non-occupational exposure of city dwellers to asbestos is believed to occur through the consumption of products containing asbestos. Urban air concentrations of 600 to 6,000 fibres per cubic metre have been estimated, however, measurements include the effects of industrial emissions, as well as natural background.

Figure 1 is a schematic representation of the flow of asbestos materials through the Canadian economy in the year 1970.

Canadian mining of asbestos fibre in 1970 totalled 1,654,000 tons total production. The majority of Canadian

asbestos is exported as fibre after milling. Crysofile asbestos accounts for over 90 percent of the world's asbestos consumption and is the only variety which is mined in Canada in any significant quantity. Approximately 95 percent of production was exported during the year 1970. On the other hand, approximately 6,000 tons of the amosite form were imported mainly for use in the manufacture of pipe insulation.

As shown in Figure 1, approximately 45 percent of the asbestos in Canada was used to manufacture asbestos cement. Approximately 18 percent went to floor tiles, ten percent was used in paving and an additional ten percent was used in coatings, caulks and sealants. The remaining uses required less than ten percent of the total.

Figure 2 summarizes the Provincial asbestos emissions for the year 1970. Canada is the western world's biggest producer of asbestos, producing approximately 35 percent of the world supply. Quebec produces over 80 percent of Canada's production which subsequently accounts for over 80 percent of the asbestos emissions in Canada.

Emissions from mining of asbestos are in the form of asbestos dust from drilling, blasting, loading, hauling and unloading operations. Additional atmospheric emissions occur during the milling process when the ore is

crushed, passed through rotary dryers and stored in dry storage bins. Although most of the atmospheric emissions of asbestos occur during mining and milling, other emissions also occur during the manufacture of asbestos products such as those made in the asbestos cement industry, where asbestos cement pipe is widely used in watermains and sewers because of low cost and excellent corrosion resistance. In addition, asbestos cement is commonly used as sheets and shingles in buildings due to its fire resistance and heat insulating properties.

Some significant emissions occur in the use of asbestos products, for example, in the construction industry where asbestos products are cut and asbestos insulation stripped from wires. The demolition of buildings also releases significant quantities of asbestos dust into urban air. However, the most significant consumptive use of asbestos is in brake linings where the heat of friction is apparently sufficient to destroy most asbestos fibres. It has been shown that the brake dust is primarily non-fibrous and therefore considered not as harmful as other forms. It is clear from Figure 2 that the most significant emissions occur in the mining and milling of asbestos.

MERCURY - SOURCES AND EMISSIONS

Mercury is the only metal which is a liquid at ordinary temperatures and thus the unique combination of having the physical properties of both a liquid and a metal has led to widespread applications of mercury in the medical, scientific and industrial fields.

The toxic nature of mercury vapour as compared to the relatively harmless nature of liquid mercury makes the evaporation process significant. In addition to elemental mercury, numerous mercury compounds, both organic and inorganic, are employed in modern society. The most toxic mercury compounds known are the methyl mercury compounds which occur both naturally and in many formulations used in industry and agriculture.

The principal area of concern for the general public has been the intake of methyl mercury via the food chain. While human activities have produced locally high mercury concentrations, and while the rate of increase of mercury by human activities has, in the last few years, been higher than the rate of release from natural processes, it is still true that at the present time man's contribution to the mercury contained in the oceans and air of the world is small with respect to the mercury which originates from natural processes

such as weathering erosion and volcanic activity. Mercury concentrations in the earth's crust vary widely with location and rock type, and the overall mercury abundance has been variously estimated to run between 50-90 ppm.

Figure 3 shows the flow of metallic mercury through the Canadian economy in 1970. 990 Tons of mercury were produced in Canada in 1970, and the only mine was in British Columbia. Conventional underground mining techniques were employed to remove ore which contained mercury compounds. The principal uses of metallic mercury are in the chlor-alkali process, the restoration of teeth with mercury amalgams, production of electrical and pharmaceutical goods and the recovery of gold.

Figure 4 summarizes the flow of mercury compounds through the Canadian economy in the year 1970. Almost all mercury compounds were imported in 1970 and were used principally in agriculture, paint manufacture, the manufacture of alkaline batteries and for pharmaceutical purposes.

Figure 5 summarizes Provincial mercury emissions in 1970. The first emission category is mercury production where emissions resulting from mining, rock handling, beneficiation, crushing and roasting the ore resulted in

less than one percent of the total mercury emissions in Canada.

The most significant mercury emissions in 1970 resulted from the consumption of mercury in the chlor-alkali industry, in which chlorine and caustic soda are produced from brine. In the chlor-alkali process the major source of mercury emission loss is in the form of mercury vapour contained in the ventilation air which passes through the electrolysis cells. Since 1970 certain of the chlor-alkali industries have stopped operating and thus total mercury emissions from these sources have decreased since 1970.

Additional environmental emissions occur through the making of dental amalgams in which mercury is mixed with a finely divided metal alloy to produce an amalgam that can be moulded. Typically, the alloy powder contains silver, tin, copper, zinc and mercury. Data from dental suppliers indicate an average annual use of seven pounds of mercury per dentist. Environmental emissions result from changes of ventilation air in dentists' offices. Further atmospheric emissions also result from the manufacture of electrical equipment, the manufacture of instruments such as thermometers and the recovery of gold.

Emissions occur from the use of mercury compounds used in fungicides and insecticides. Atmospheric emissions consist of mercury compounds lost during spraying operations and also mercury vapour given off from mercury compounds on foliage, fruit or soil surfaces.

Mercury emissions also occur during the manufacture of certain types of paints. Inorganic compounds such as mercuric oxide and mercuric sulphide are used as red pigments while phenol mercury compounds are widely used as preservatives and fungicides to combat the feeding of micro organisms on the oils and proteins in the paint. Organic mercurials also inhibit the staining of paint by sulphide pollutants in the air. The emissions resulting from paint manufacture are insignificant compared to emissions from paint application. Mercury and mercury compounds are also consumed in a wide variety of other uses such as pharmaceuticals, however, emissions are small.

Inadvertent mercury emissions can result in significant amounts. Areas of concern include the applications of paint containing mercury additives, burning of fuels with trace amounts of mercury, incineration of sludge or waste refuse and the recovery of base metals from ores which contain trace amounts of mercury.

Furthermore, trace amounts of mercury in wood resulted in over two tons of atmospheric mercury emissions from forest fires in 1970.

Miscellaneous sources of mercury emissions include such things as the disposal of spent fluorescent tubes wherein the mercury vapour will be lost to the air when the tube is broken and from the breakage of mercury thermometers. It has been estimated that about 1.8 million medical thermometers, which contain a total of approximately 8,000 pounds of mercury, are broken each year.

LEAD - SOURCES AND EMISSIONS

Man's use of lead has a long history. The wide availability of lead ores and the low melting point of lead which facilitates the recovery of lead from the ores, have contributed to its very early use.

Lead and several lead compounds occur naturally in the earth's crust. Therefore, lead which is released through weathering will circulate through the environment entering air, water, soil, plants and animals.

Although the bulk of ingested lead is presently absorbed through dietary processes, respiratory lead intake has increased during the past decades.

Lead is one of the most widely used non-ferrous materials. Figure 6 illustrates the flow of lead through the Canadian economy in 1970. Canada was the non-communist world's third largest lead producer at that time, following only the United States and Australia. Principal sources of lead mined in Canada were the Northwest Territories, British Columbia, Yukon Territory, and New Brunswick, with a production of 389,000 tons of ore. Exports accounted for the bulk of the lead production and approximately 166,000 tons of lead were exported in ore or concentrated form, while an additional 165,000 tons were exported as lead metal materials or scrap. Consumption of lead by Canadian industry in 1970 was approximately 93,000 tons. Approximately 60 percent of this consisted of domestic primary lead.

Lead metal is widely used for its corrosion-resistance in construction, water pipes, chemical equipment, electrical cable sheathing and storage batteries. Since lead is soft and malleable it is used for ammunition, packaging and production of collapsible tubes. As a result of its low melting point it is commonly employed as printing type, for solder and for casting minerals. Frictional properties of lead generate applications in bearings and machineable alloys and as a result of its high density it is utilized as radiation shielding, acoustical insulation and ballast.

Lead compounds, in particular, tetraethyl lead and tetramethyl lead, are still widely added to gasoline as anti-knock additives. Lead oxides are used in the production of litharge for ceramics, insecticides, oil refining, rubber compounding, varnish manufacture and in the production of storage batteries. Lead arsenate is applied as insecticide, and lead and lead compounds are included in a multitude of other applications. Most of the lead required in the production of manufactured goods was used to make batteries, lead containing chemicals, solders, cable sheathing and in the production of semi-finished products.

The Provincial lead emissions for the year 1970 are summarized in Figure 7. Atmospheric emissions resulting from the production of lead occur through changes of the mine ventilation air, the dust produced by the milling process and through the transportation and handling of lead ore. However, dust suppression equipment such as cyclone scrubbers or baghouses are widely used both to protect workers and the environment, and to permit recovery of valuable lead metal.

Significant emissions of lead in the form of lead sulphides, lead oxides, and metallic fumes occur during the smelting process. Lead emissions also occur from

the production of secondary lead. The recovery of lead from battery plates, cable sheathing, scrap metal and various slags and drosses accounted for approximately 35 percent of the lead consumed in Canada in 1970. Good control techniques are widely used in the secondary lead industry in an effort to protect the worker and the environment, and to recovery valuable lead minerals.

A variety of sources fall into the manufacturing category. Battery manufacture produces atmospheric emissions from internal smelting operations, the production of lead oxides and from various castings and lead burning operations. The second largest use of lead in Canada following battery manufacture was in the manufacture of the lead gasoline additives, tetraethyl and tetramethyl lead.

Some atmospheric emissions also result from the production of litharge or lead oxide used in storage battery manufacture, in paint manufacture and as the starting ingredient in the manufacture of many lead compounds. Baghouse control of exhaust air traps well in excess of 90 percent of the particulate.

Significant lead emissions also resulted from metal fabricating industries; for example, in the production of lead alloys in melting pots, manufacture of collapsible tubes, manufacture of ammunition and plumbing goods, the coating of electrical cables and the casting,

grinding and machining of lead alloys.

Emissions of lead to the atmosphere also occur through the consumption of lead products, the most significant source of which is combustion of gasoline containing lead anti-knock compounds. An estimated 98 percent of lead emissions from gasoline are produced during combustion, although the quantity, chemical form, and particle size distribution of emissions to the atmosphere vary with the type of vehicle, condition of the vehicle and with operating conditions. The consumption of lead additives in automobile gasoline accounted for approximately 66 percent of the total environmental lead emissions in 1970.

Lead emissions also occur from the consumption of solder and at newspapers employing hot letter press operations which involve the use of lead alloys. Lead emissions originate from the melting kettles used to hold the molten lead necessary for preparing the type. In addition, significant lead emissions arise from the manufacture of paint.

Inadvertent lead emissions result from trace quantities of lead which are present in a variety of materials, such as coal. Trace amounts of lead are present in trees and thus forest fires resulted in an estimated 36 tons of lead to be released to the air in 1970.

Significant lead emissions can also occur as a result of the incineration of waste refuse and sewage sludge as well as a large variety of other activities such as the manufacture of portland cement, and the application of lead containing insecticides.

The Provincial emissions of asbestos, mercury and lead are summarized in Figure 8, where it is clear that Ontario and Quebec are the source of most atmospheric emissions.

SOURCE TESTING

Once a particular sector or industry has been identified as a potential significant emitter, the emissions should be quantified more precisely. In the past our firm has used a variety of techniques, including soil sampling, ambient air measurements and dispersion modeling to study emissions.

However, stack testing represents the ultimate proof of emissions, emission rates, and control efficiencies. Moreover, stack testing can provide detailed design data. Alternative methods of obtaining this information may be by means of a process mass balance or published emission factors. Considering the capital expense involved in installing a control device, it is important that the design is based on reliable data.

Emission factors obtained through testing surveys of industrial installations provide pounds per hour contaminant emission rates based on amount of product produced. These factors represent average values and do not take into account the specific differences between plants.

For example, tests of a 37.5 ton lead alloying kettle established an uncontrolled emission of 0.78 pounds of total particulate per ton of lead alloyed. This is in close agreement with the United States Environmental Protection Agency emission factor for particulates of 0.8 pounds per ton.

On the other hand, tests on a small domestic incinerator established an uncontrolled emission of 63.4 pounds of total particulate per ton of solid waste burned. This deviates from the United States Environmental Protection Agency's emission factor of seven pounds per ton by close to one order of magnitude.

The difference between the two calculated emissions using emission factors can be attributed to variations in types of waste burned, detail difference in incinerator construction and the fact that the tests were not conducted during optimum incinerator operation. These shortcomings of emission factors are often criticized in assess-

ment of emissions and the effect on ambient air quality. Compliance testing for the authorities can settle many disputes. Nonetheless, in practice many problems arise in the field which makes it difficult to fully comply with Federal or Provincial Source Testing Codes in all situations.

As an illustration, let us consider some problems encountered in recent source tests performed for a variety of lead handling industries. Extraordinarily long sampling times may be required in order to obtain sufficient sample quantity for analysis. The Ontario Ministry of the Environment requirement of a 60 cubic foot sample is often too small when low concentration emissions are sampled after a high efficiency control device. A larger 120 cubic foot sample is required and this necessitates a prolonged sampling period. When tests are performed on batch or cyclic processes the emission rates determined will indicate the average emissions and will not display possible emission peaks.

In order to determine the collection efficiency of existing control devices or to obtain design parameters it is often necessary to know the particle size distribution of the waste gas stream. A cascade impactor can be used for this purpose. However, its use is impractical for

sizing low level emissions. The cascade impactor plugs severely when emission rates are high.

On the basis of our experience we suggest that cascade impactors should not be used for source testing and particle size analyses if the concentration of particulate in the gas stream is less than 0.001 grains per standard cubic foot or greater than 1 grain per standard cubic foot.

Since we are concerned with very small amounts of material, sample recovery is critical and filter collection media and wash reagents should have blank tests to establish background levels which may affect the final value of the pollutant captured. For example, repeated blank tests on glass fibre filters have shown a high and irregular occurrence of zinc, thus when testing for zinc or zinc alloys a membrane filter should be substituted for a glass fibre filter.

Figure 9 summarizes some recent test results and serves to illustrate the variation amongst similar sources that exist in Ontario. The significant variation between source testing and estimates made using published emission factors is also shown in Figure 9.

CONCLUSION

As illustrated by Figure 8, the most significant emissions of asbestos, mercury and lead occur in Ontario and Quebec. The test results shown in Figure 9 show that although emission factors are suitable for inventory and environmental assessment purposes, the published emission factors are not as accurate as source sampling for design, abatement or compliance purposes.

ASBESTOS , 1970

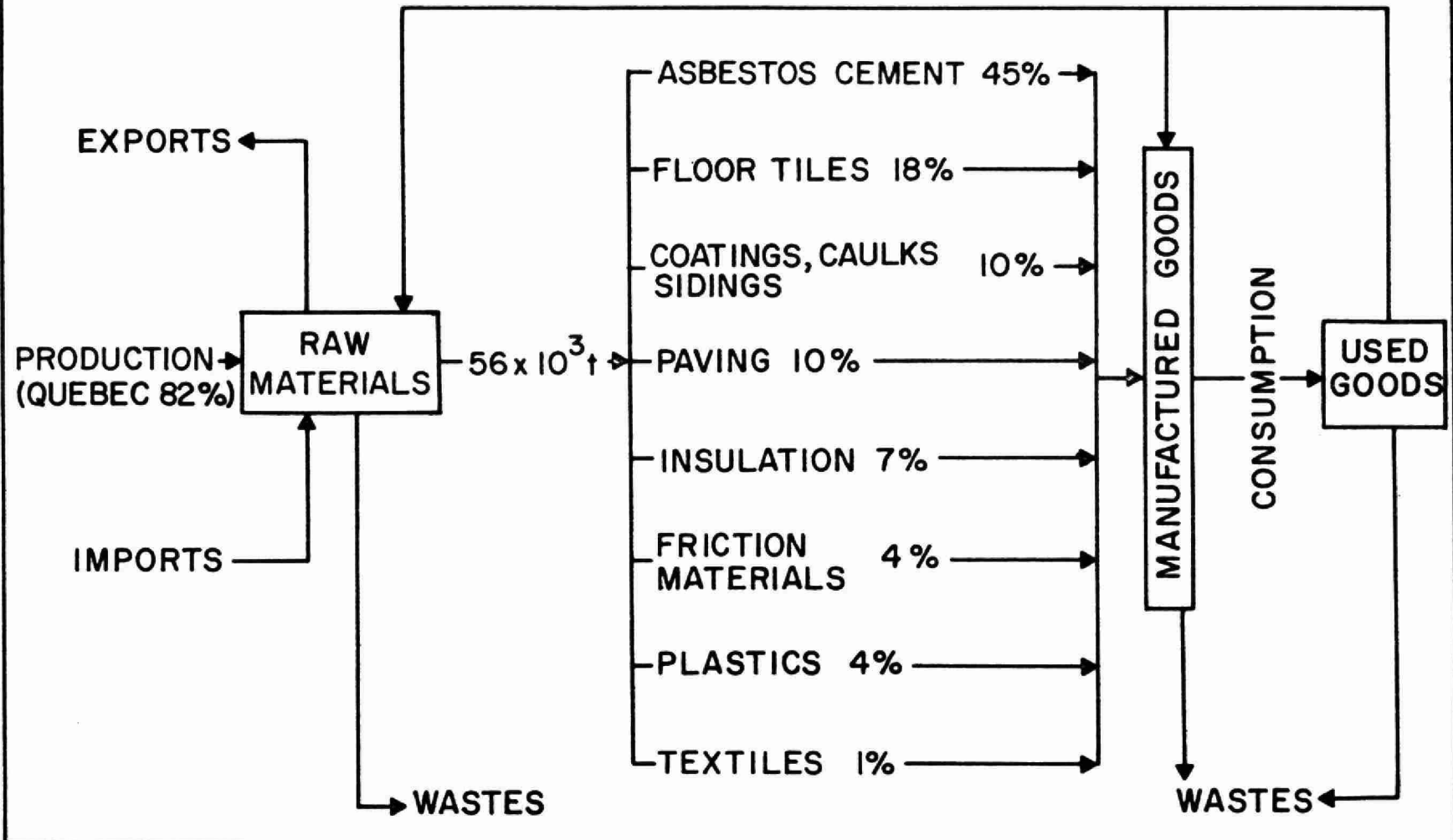


FIGURE 1

1970 PROVINCIAL ASBESTOS EMISSIONS (%)

PROVINCE	PRODUCTION	BRAKE LININGS	ALL SOURCES
ATLANTIC	4.0		4.0
QUEBEC	81.3	0.14	81.5
ONTARIO	2.3	0.2	2.5
MANITOBA			
SASKATCHEWAN			
ALBERTA			
BRITISH COLUMBIA	5.4		5.4
YUKON & N.W.T.	6.5		6.5

"
 1.6×10^4 tons

FIGURE 2

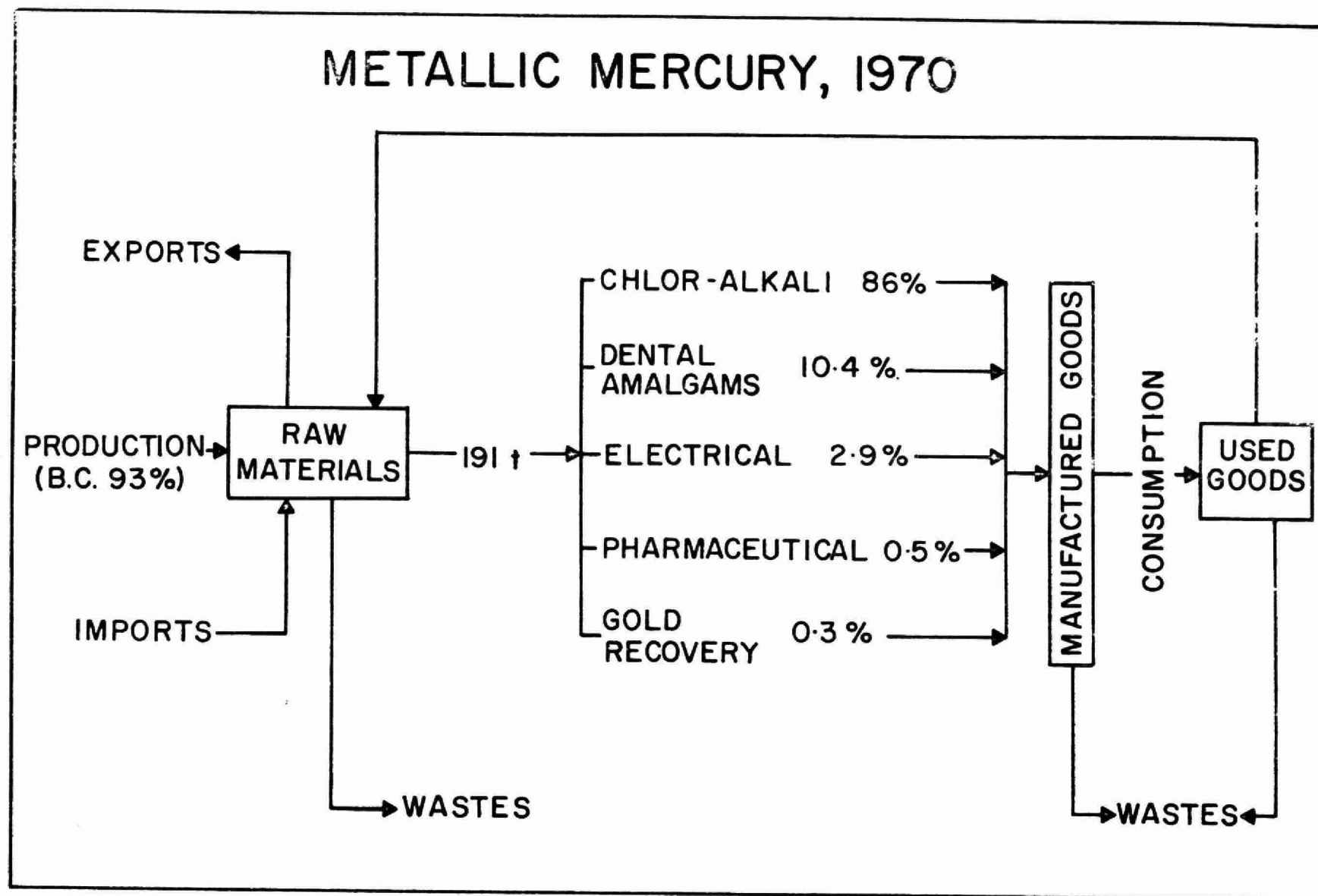


FIGURE 3

MERCURY COMPOUNDS, 1970

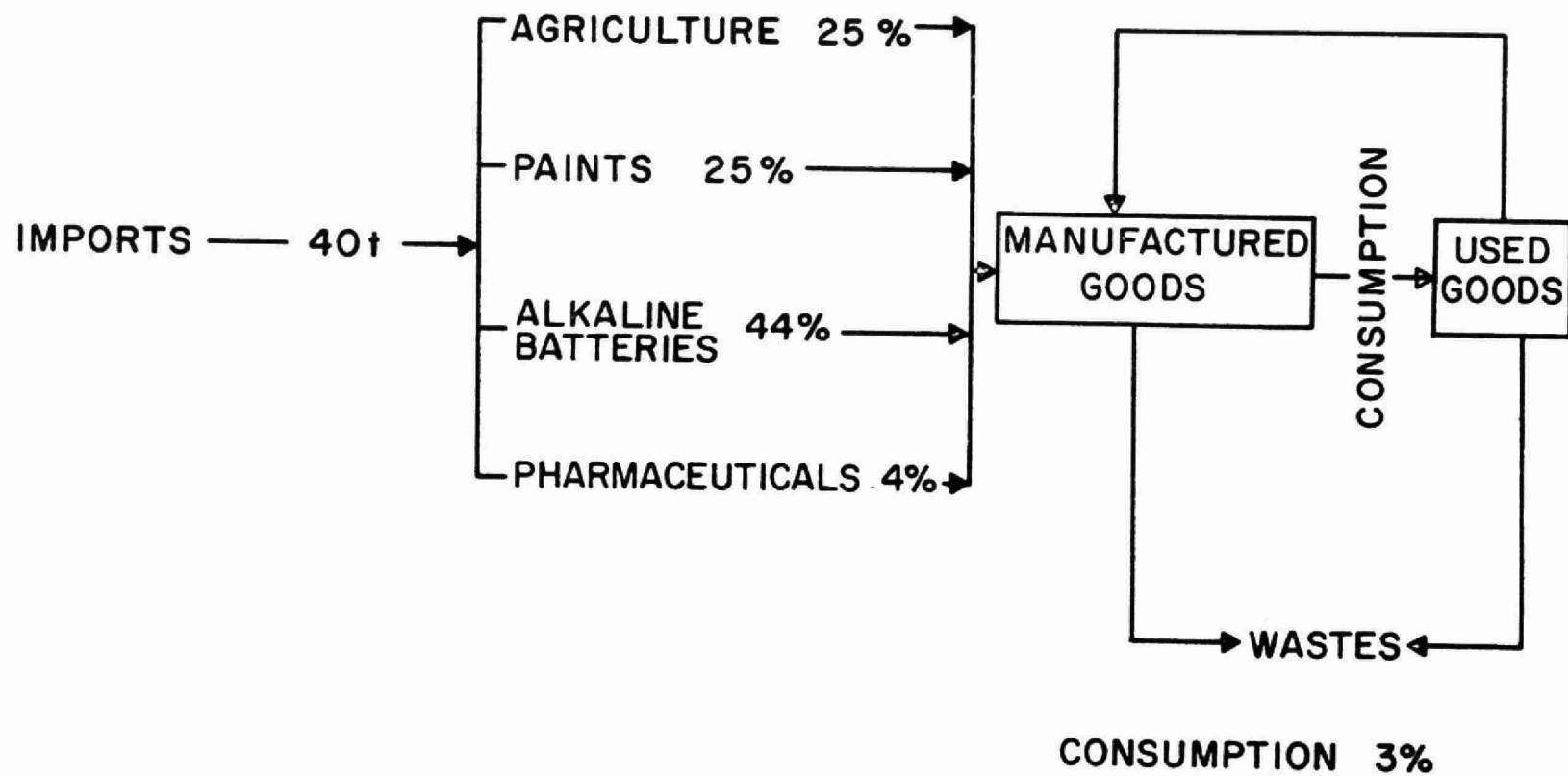


FIGURE 4

1970 PROVINCIAL <u>MERCURY</u> EMISSIONS (%)					
PROVINCE	PRODUCTION	CONSUMPTION	COMPOUND CONSUMPTION	INADVERTANT	ALL SOURCES
ATLANTIC		2·4		6·1	8·7
QUEBEC		9·3	0·6	17·2	27·1
ONTARIO		15·6	0·9	19·8	36·3
MANITOBA				7·5	7·7
SASKATCHEWAN		1·6		2·5	4·3
ALBERTA				2·8	3·2
BRITISH COLUMBIA	0·22	3·8		5·8	12·0
YUKON & N.W.T.				0·7	0·7
					82·2 tons

FIGURE 5

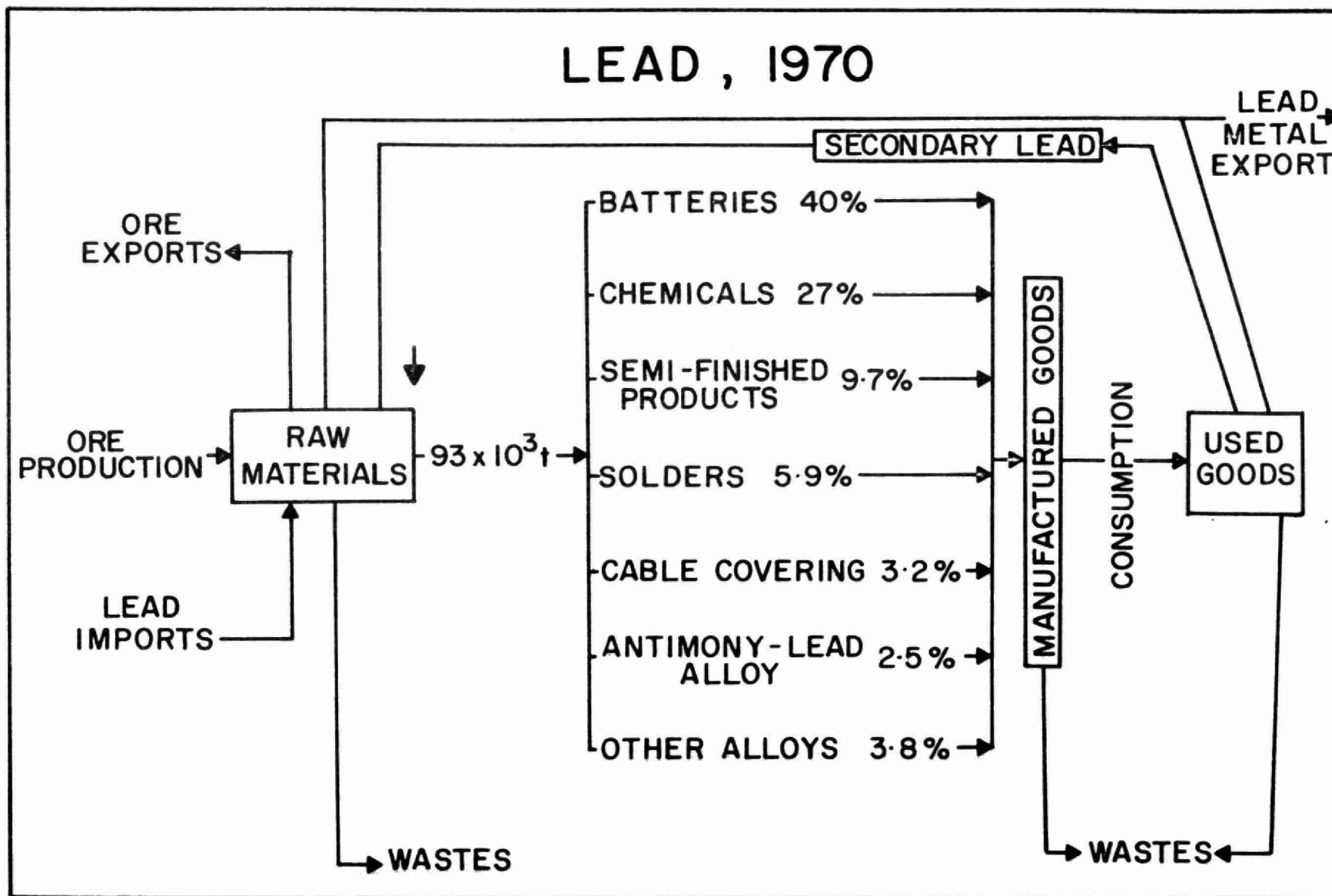


FIGURE 6

1970 PROVINCIAL LEAD EMISSIONS (%)

PROVINCE	PRODUCTION	MANUFACTURING	CONSUMPTION	INADVERTANT	ALL SOURCES
ATLANTIC	2.6		5.3	4.0	11.9
QUEBEC			16.7	11.0	27.7
ONTARIO	0.3	0.4	24.2	9.9	34.8
MANITOBA			3.1	0.3	3.4
SASKATCHEWAN			3.9		3.9
ALBERTA			6.6		6.6
BRITISH COLUMBIA	2.0		6.6	0.3	8.9
YUKON & N.W.T.	2.2		0.3		2.5

11
2.1 x 10⁴ tons

FIGURE 7

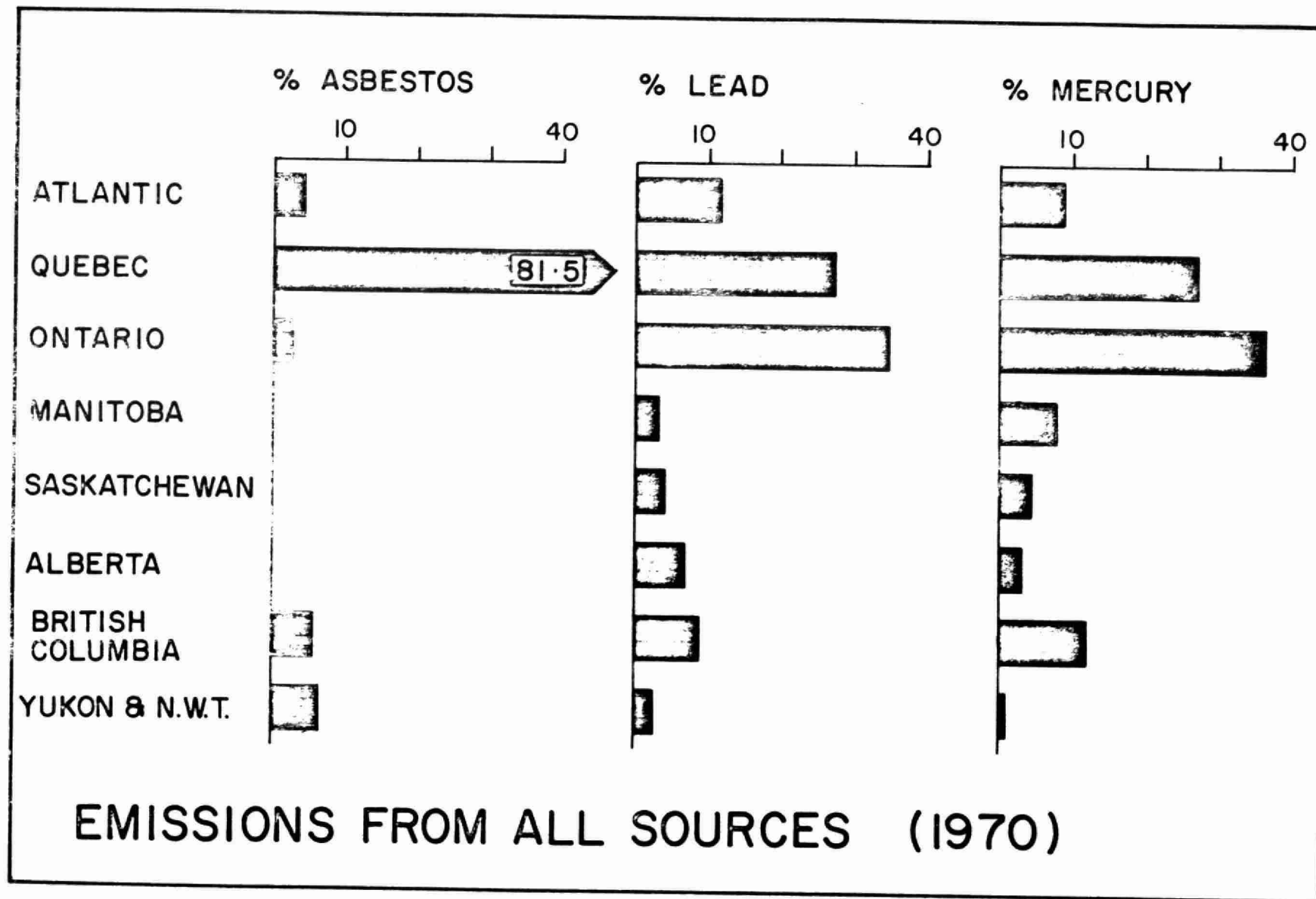


FIGURE 8

UNCONTROLLED LEAD PROCESS EMISSION FACTORS PARTICULATES

<u>PROCESS</u>		<u>SOURCE TEST RESULT (lb/ton)</u>	<u>EPA * FACTOR (lb/ton)</u>
<u>BRASS INGOT</u>			
INDUCTION FURNACE	case (a)	0.30	2
	case (b)	9.0	2
<u>SECONDARY LEAD</u>			
REVERBERATORY FURNACE		9.6	56 - 313 (Avg 147)
POT (Alloying)	(a)	0.78	0.8
POT (Melting)	(b)	0.036	0.8

* COMPILATION OF AIR POLLUTANT EMISSION FACTOR (April 1973 & revisions)

FIGURE 9

ASBESTOS IN THE ENVIRONMENT

EXTENT, EFFECTS

Extensive knowledge exists of the hazard associated with occupational exposure to asbestos fibres. Asbestosis, lung cancer, pleural and peritoneal mesothelioma, and gastrointestinal cancer are found in excess among various asbestos-exposed work groups. Since 1960 data have accumulated indicating that asbestos-related disease extends beyond the work-place boundry into the neighbouring community and the homes of workmen.

One special source of concern has been the use of asbestos in the construction industry, particularly the spray application of asbestos for fireproofing of the steelwork of high-rise office buildings, which has now been banned in the United States.

In addition to sources of commercial varieties of asbestos, concern also exists over the dissemination of waste materials containing other asbestiform minerals, such as, the air and water pollution associated with the emissions from taconite ore processing.

by

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Dr. Nicholson, a biophysicist, is on the staff of the Environmental Science Laboratory of the Mount Sinai School of Medicine, where he is an Associate Professor. He directs a number of epidemiological studies to define the extent of occupational disease in a variety of industries, including, most recently, PVC workers exposed to vinyl chloride, and several groups of asbestos-exposed workmen. In addition, he has conducted a variety of environmental evaluation studies in several occupational areas and has also developed techniques for the measurement of asbestos in air and water. Presently his activities include analytical work for the United States Environmental Protection Agency in connection with its suit against the Reserve Mining Company of Minnesota.

ASBESTOS IN THE ENVIRONMENT: EXTENT, EFFECTS

by

William J. Nicholson, Ph.D.

The history of asbestos disease dates from the turn of the century, when two reports were published documenting the severe conditions in asbestos textile factories. One, the published testimony of Dr. H. Montague Murray at a compensation hearing, described the severe pulmonary fibrosis found at autopsy, in 1900, in the last survivor of a group of ten workers employed 14 years previously in a carding room. At the time of the hearing, in 1906, Dr. Murray offered the optimistic prognosis, "One hears, generally speaking, that considerable trouble is now taken to prevent the inhalation of dust, and so the disease is not so likely to occur as heretofore." (1) The second was the description by Auribault (2) of an extreme mortality during the first five years of operation of an asbestos weaving mill established at Conde-sur-Noireau, France, in 1890. During this period, 50 men died, including 16 of 17 recruited from a cotton textile mill previously owned by the factory director.

Subsequently, various cases of pulmonary fibrosis following inhalation of asbestos were published in the medical literature, including one by Cooke (3) who gave the disease its current name, asbestosis. A 1929 study by the British Factory Inspectorate of asbestos textile operations revealed the extent of the continuing problem. (4) In a clinical survey of mill employees, 80% of those employed for 20 or more years had X-ray evidence of asbestos disease. This finding stimulated the Factory Inspectorate to require the introduction of extensive environmental control technology in the industry and to establish an ongoing medical surveillance program. Again an optimistic prognosis was issued, "The outlook...is good...In the space of a decade, or thereabouts, the effect of energetic application of preventive measures should be apparent in a great reduction in the incidence of fibrosis."

In time, however, the spectrum of disease from asbestos exposure continued to expand. In 1947, lung cancer was found in 13% of individuals who died with asbestosis in Great Britain. (5) Mesothelioma, a rare tumor of the lining of the abdomen or chest, was described in an asbestos worker in 1954 (6) and unequivocally associated with asbestos exposure in 1960. (7) Gastrointestinal cancer, also was found to be in excess among asbestos insulation workers in the United States. (8)

In 1975, three-quarters of a century after the first identification of asbestos-related disease and deaths, society continues to be plagued by their presence; unfortunately in ever increasing amounts. Moreover, the population at risk from the several asbestos-related diseases has expanded from those directly working with mineral, to those working nearby the application or removal of asbestos materials, and to those who simply live in the vicinity of an asbestos operation or in the household of an asbestos worker. In each of the categories of exposure, occupational, indirect occupational, and environmental, the understanding of certain features is important for the alleviation of current disease and the prevention of future disease.

High Exposure Effects

Four ongoing mortality studies at the Environmental Sciences Laboratory of the Mount Sinai School of Medicine in New York illustrate the increased risk of death associated with past, high occupational exposures to asbestos. The greatest increase in mortality occurs in factory populations. A study of 20-year hourly employees of the largest U.S. asbestos products manufacturing facility reveals the presence of the full spectrum of asbestos-related diseases. (9) In this study, the mortality experience of all 689 individuals who were working on January 1, 1959, and who were first employed prior to 1939, was documented. From 1959 through 1971 it

was expected that about 134 deaths would have occurred in this population. Instead, 199 died, 50% more than should have. Table 1 lists a detailed breakdown of expected and observed deaths, by cause, during this period.

In this factory, the union officials were able to categorize jobs according to relative dustiness. The rankings included jobs with little asbestos exposure, such as those in departments that did not use the mineral, as well as the dusty operations, those in the textile mill, pipe departments, or thermal insulation. The estimates are quite accurate, as can be seen by considering the percentages of deaths from asbestosis in different dust categories, shown in Table 2. The highest category was the textile mill, where it was found that over 40% of the deaths occurred from asbestosis. This percentage decreased as dustiness was reduced until, in the lowest category, less than 5% of the deaths were due to asbestosis. Considering this table, the disconcerting feature is that even though deaths from asbestosis were reduced, those from cancer were not. Thus, airborne asbestos concentrations that may not greatly increase the risk of death from lung scarring may still produce a significantly increased risk of death from the various asbestos-related cancers. This point gains importance when one considers that the current British standard and the United States standard, which in turn was derived from it, were primarily established to protect against asbestosis. Information was not available that would allow a level to be set that would protect against cancer.

In another asbestos products manufacturing facility, one that operated from 1941 through 1954, a similar, severe occupational problem is seen.⁽¹⁰⁾ Table 3 lists the expected and observed deaths by cause among 933 amosite factory workers who were employed for any time between 1941 and 1945. Noteworthy in this study is the evidence of asbestos disease

from short-term exposure. Table 4 shows the expected and observed deaths from lung cancer among individuals who worked for less than three months, from three months to a year, and over one year. Even in the shortest exposure, lung cancer is nearly four times in excess.

Dose-Response Estimates

The third cohort, that of the membership of the New York and New Jersey locals of the Asbestos Workers Union, is especially important because information also exists on the environmental exposure of these workers. Table 5 shows the mortality experience through 1973 of individuals who had 20 or more years since first exposure to asbestos. Over this period, 444 men died, whereas only 300 deaths should have occurred. Looking at the causes of death, it is not difficult to identify the sources of excess mortality. Lung cancer, asbestosis, gastrointestinal cancer, and mesothelioma are all found in excess. Among those who died, one in five died of lung cancer; one in twelve from asbestosis; one in ten from gastrointestinal cancer; and one in thirteen from mesothelioma. The distribution of deaths is very similar to that of the lowest dust category in the asbestos products manufacturing facility. Considering the expected frequency of these various cancers in this population, nearly 40% of the deaths of these workers can be attributed to their occupational exposure to asbestos.

One noteworthy feature of the data in Table 5 is that in the first nine years of observation, there were actually fewer deaths than expected. This is a common occurrence in mortality studies of working populations; individuals employed at the start of a study are healthier than many in the general population and this is usually reflected in a lessened mortality risk. It is worth noting, however, that even in these first few years, the excess asbestos-related cancers can be seen.

The data on the health experience of insulators are important because information also exists on their environmental exposures. Thus, we can relate observed asbestos disease with estimates of asbestos fiber concentrations. Using the standard membrane filter technique proposed by the United States Public Health Service for counting asbestos fibers, three different laboratories in the United States (11, 12, 13) have found that the average concentrations of asbestos dust in insulation work between 1968 and 1971 ranged from three to about six fibers per milliliter (f/ml). A similar study, in the Devonport Naval Dockyard, (14) in Great Britain, using the same techniques, obtained 8.9 f/ml for the average of long-term samples of asbestos concentrations measured during the application of insulation materials aboard ship. These data represent average levels when men were working with asbestos-containing materials. However, over half the time of U.S. insulation workers during these years was spent using other materials - fibrous glass, mineral wool, polyurethane, etc. Considering this distribution of their work activities, the overall time-weighted average exposure of United States asbestos workers in the late 1960's was less than 3 f/ml.

In the research that led to these data, it was reported that peak exposures could be extremely high. It was not uncommon, for example, for two to five-minute concentrations of asbestos to range between 50 f/ml and 100 f/ml during the mixing of cement. This mixing, however, would consume only a few minutes time and be done perhaps once an hour. Thus, exposures measured over that hour, including the mixing, would seldom average over 5 f/ml. Similar experiences were subsequently reported by Cooper, (15) at Lyon, who stated that, "Peak concentrations may be high for brief periods, while time-weighted averages are often deceptively low."

We have direct information on asbestos fiber concentrations, measured using the currently prescribed analysis procedures, during recent years only. Insulation materials have changed from earlier years. Fibrous glass has found extensive use, while work with cork is seldom seen today. Moreover, changes in the asbestos composition of insulation products have taken place. Pipe covering and insulation block may have had twice the asbestos content in past year as they have today. During this period, however, work practices were virtually identical to those of past years and during the period of these measurements, few controls of significance were in use. Thus, dust concentrations measured under these conditions have relevance for the estimate of levels of past years. Considering the possible doubling of asbestos content of insulation materials, and considering that workers may have used asbestos materials more often in the past than now, the data from these three studies would suggest that the insulators' average exposures in the United States during past years would range from 10 to 15 f/ml.

The only early research of note on asbestos dust concentrations in past insulation work is the 1945 study of Fleischer and his colleagues,⁽¹⁶⁾ who reported asbestos dust levels during insulation application in four U.S. shipyards. In this study, dust concentrations were assessed using a konometer (an instrument widely used at that time, but no longer employed), and both total dust and fiber levels were recorded. The study is difficult to evaluate, as the average dust levels reported in different shipyards varied by nearly 100 times. In two yards, average dust concentrations of about 1 f/ml were found; in a third yard, 90 f/ml; and in the fourth, 35 f/ml. During 1965 and 1966, the fourth yard was resurveyed by personnel of the Department of Industrial Hygiene, Harvard School of Public Health.⁽¹⁷⁾

In the resurvey, a time-weighted average exposure of about 8 f/ml was determined.

These fiber counts represent all fibers visible in the field of view of a konimeter. Fibers perhaps as short as 1.5 microns (μ) would be enumerated. Supplementary data ⁽¹⁸⁾ on the size distribution of amosite aerosols in shipyards suggest that this overestimates the number of fibers longer than 5 μ by a factor of two. If we take this factor into account, and simply average the data from the four shipyards studied by Fleischer in 1945, an estimate of from 15 to 20 f/ml is obtained for average asbestos concentrations in insulation work during this period. Similar considerations would yield a value of 4 f/ml for the shipyard survey by Murphy in 1965. It must be emphasized, however, that averages are highly subjective and depend strongly upon the vagaries of the particular work practice selected for sampling and the conditions present at that time.

These summaries of asbestos concentrations from 1945 through 1971 by five different research groups in two countries are summarized in Table 6. The estimate of from 10 to 15 f/ml for past insulators' average asbestos exposure in non marine work and 15 to 20 f/ml for marine work does not offer much confidence that 5 f/ml, or even 2 f/ml, is sufficient to protect asbestos workmen. Forty percent of insulators' current deaths can be attributed to their past occupational exposure to asbestos at such levels. A standard set at two, or even five times lower, is unlikely to offer the necessary protection to asbestos workmen.

Lapsed Period

Few serious effects from asbestos exposure are seen prior to 20 years from onset of first exposure. Table 7 shows the expected and observed deaths among 17,800 asbestos insulation workers in the United States and

Canada. ⁽¹⁹⁾ While some excess mortality can be seen in the population with less than 20 years from onset of exposure, the total number of deaths in this group is small as its members were relatively young. However, after 20 years from onset of exposure, the percentage of excess deaths, particularly of cancer, and the total number of deaths increase significantly. Table 8 lists the expected and observed deaths from lung cancer in five-year intervals from first exposure. Here, both the number of observed deaths and the ratio of observed to expected deaths peak after 30 years from onset of exposure. A more dramatic illustration of this effect of time is shown in Figure 1, where the excess lung cancer risk, normalized to an equal population within each time interval, is plotted. The significant increase in risk after 30 years is clearly seen.

Synergistic Effect

Increasing evidence is accumulating that many cancers may have a multiple-factor etiology. For example, lung cancer in asbestos workers is strongly associated with cigarette smoking. In the large cohort of 17,800 insulators observed by Selikoff ⁽¹⁹⁾ the smoking habits were obtained on the majority of workers at the beginning of the study. Table 9 illustrates the effect of cigarette smoking on lung cancer mortality. In 2066 non-cigarette smokers, only two lung cancers were seen in a six-year period; 179 were observed in 9590 men with a history of cigarette smoking. While the data are too scant to determine a risk of dying of lung cancer in non-cigarette smoking asbestos insulators, they do suffice to establish that the risk is less than that of cigarette smoking in non-asbestos-exposed males in the general population. However, the combination of cigarette smoking and asbestos has a multiplying effect. From data on the New York and New Jersey insulators cohort, it has been calculated that the combined

risk for dying of lung cancer is 92 times that of an individual who neither smokes nor works with asbestos.

Indirect Occupational Asbestos Exposures

The most extensive documentation of indirect occupational asbestos disease is that found in the shipbuilding industry, primarily in Great Britain. In 1968 it was pointed out by Harries⁽²⁰⁾ that workers other than insulators were at risk of asbestos disease. In a survey of employees of the Devonport Dockyard, X-ray evidence of asbestos exposure was found in 12 non asbestos workers, including a plumber, electrician, carpenter, etc. Five cases of mesothelioma were also found, all in other than insulation workers. Continuing to follow this group of workers, Harries has now documented 37 cases of mesothelioma in the Devonport Dockyard alone.⁽²¹⁾

A study of the distribution of cases of mesothelioma found in Scotland between the years 1950 and 1967 is particularly revealing.⁽²²⁾ Of 80 cases available for study, 55 were in shipyard employees, dockers, or naval personnel. Of the 55, only one was in an insulation worker. Table 9 shows the years in which the various cases were diagnosed. Throughout the fifties, perhaps one or two cases a year were found; but, in the sixties, a rapid increase was seen, following a 25 to 30-year lapsed period from the increased shipbuilding activity prior to World War II. It is noteworthy that in the United States shipbuilding industry, increased productivity followed that of Great Britain by about five years. Thus, the effects of the United States use of asbestos in shipyards are only now beginning to be seen. Table 10 lists the U.S. shipyard employment by years through 1944.⁽²³⁾ From such data and information on employment turnover, it is estimated that 4,500,000 men and women worked in shipyards at some time between 1940 and 1945. Over 3,000,000 of these individuals are alive today and at some excess risk for

mesothelioma or bronchogenic cancer. Such numbers speak loudly for the need to develop techniques for early diagnosis and effective treatment of such diseases.

A third important study of British shipyards is that of John Edge,⁽²⁴⁾ who reviewed X-rays of shipyard workers in Barrow. A prospective study was conducted of 235 men whose X-rays taken between 1955 and 1969 showed abnormalities characteristic of asbestos exposure (pleural plaques). Most of these X-rays were of individuals who did not work directly with asbestos on a daily basis. In tracing the individuals who had such X-ray evidence, it was found that 70 had subsequently died; of the 70 deaths, 17 were of mesothelioma and 13 were of bronchogenic carcinoma. While the pleural fibrosis found in these individuals was insufficient to produce any disability, the fibers present in the chest were of sufficient quantity to greatly increase the risk of asbestos-related cancers.

Environmentally-Related Disease

The documentation of the effects of environmental asbestos exposure actually predates the knowledge of indirect occupational disease. In 1960 Wagner⁽⁷⁾ discussed 47 cases of mesothelioma found in the Northwest Cape Province, South Africa. Of this number, roughly half were in individuals who had simply lived or worked in the area of asbestos mining or along the roadways by which asbestos fibers were shipped. Further documentation came in 1964 in a case-control study of Newhouse and Thompson⁽²⁵⁾ of mesothelioma deaths in the London Hospital. Of 76 cases available for review in the pathology files, roughly half were of occupational origin; but of the remaining 34, eleven were in individuals who lived within one-half mile of an asbestos factory, and nine in individuals who lived with asbestos workers.

A recent extensive study of the effects of family exposure has been conducted by Dr. Henry Anderson of Mount Sinai School of Medicine.⁽²⁶⁾ In a clinical study of 210 family members of former factory workers, it was found that 38% of these individuals had X-rays with abnormalities characteristic of asbestos exposure. Table 11 lists the percentages of abnormalities found and Table 12 the family relationships of the individuals in whom they occurred. It did not matter what the relationship to the worker was; the asbestos dust in the household affected all. If one recalls the study of Dr. Edge in Barrow, the prognosis for individuals with such changes is disturbing. While many may suffer no impairment whatsoever from their past asbestos exposure, some are virtually certain to develop one of the asbestos-related cancers as a result of their past household exposure. Already, in 252 deaths identified in family members of the group of factory workers, two cases of mesothelioma have been found. Additionally, two other mesothelioma cases have been identified in living members of this group. These cases have the following histories:

A.C.: The 40-year-old son of a man who worked from 1945 through 1948 in the plant, when the son was 11 years old.

B.P.: The 41-year-old daughter of the plant's chief engineer.

I.Y.: The 42-year-old daughter of a man who had worked in the plant for five years. The family lived near the plant and the daughter used to bring her father lunch every day, when she was 10 years old.

L.N.: A 32-year-old woman who, at the age of 13, lived in the home of her brother-in-law while he worked at the plant for six months. Prior to that she lived one-half mile from the plant and played frequently in the homes of friends whose fathers worked in the plant.

Numerous other asbestos exposures to the general population occur in addition to neighborhood and family exposures from manufacturing processes. One of the most widespread in past years was that from the practice of spraying asbestos-containing fireproofing materials onto the steelwork of

high-rise buildings. During this process, extensive overspray occurred and the asbestos was widely distributed about construction sites. This process was finally prohibited in the United States; first in some municipalities--Boston, New York and Philadelphia--and finally across the nation, in 1973. Because of the long lapsed period between exposure and disease, however, we will not be able to assess the legacy of disease from this process perhaps until 1993. In addition to the environmental exposures of the past, there are two other legacies from this process that may be equally serious. One is the situation that must be confronted when buildings to which asbestos-containing spray fireproofing was applied are demolished. At the present time, there is no procedure that can assure containment of the asbestos to the worksite. Environmental contamination exceeding even that of past years may occur unless new and effective procedures are developed for removal of this material. Finally, there is the continuing legacy of the contamination of building air supplies from the use of asbestos-containing fireproofing materials in return air plenum spaces. Here, because of the cost of heating or cooling building air, 80 to 90 percent of the return air is recirculated through the building after undergoing minimal filtration. Thus, erosion of asbestos in the return air plenum can contaminate the air in all spaces in high-rise office buildings.

To test this possibility, we have measured the asbestos concentrations in building air of structures in which dry-type and cementitious asbestos fireproofing have been used, as well as buildings in which no asbestos was used for fireproofing purposes. Figures 2 and 3 show the distribution of asbestos in these various circumstances. It can be seen that air supplies of buildings in which dry-spray asbestos was used are often contaminated. A need clearly exists to develop an effective filtration system to minimize

this insidious form of contamination.

One source of asbestos emissions into the environment that must be carefully controlled is the disposal of waste materials, first from the extraction and production operations and, secondly, from the application and use of finished products such as thermal insulation or asbestos cement boards and pipes. Finally, the removal of asbestos once applied presents an ongoing problem. Asbestos materials applied as fireproofing have already been discussed. Other products, particularly those used in thermal insulation on pipes and boilers, are often removed. Careful wetting prior to removal has been found to be the only feasible method of reducing dust concentrations. Here, the importance of education cannot be minimized. Engineering departments responsible for removal or conversion of old insulation materials must be made aware of the health problems that may be associated with such work.

When considering the problems associated with the disposal of asbestos-containing wastes, one should also be aware that asbestos may be a contaminant of other materials. The most notable example of this situation is the asbestos mineral contamination of taconite ore wastes now being discharged into Lake Superior. The Reserve Mining Company at Silver Bay, Minnesota, discharges approximately 70,000 tons of tailings daily. In the residue of these tailings are amphibole minerals of the cummingtonite-amosite-grunerites series, analogous in chemistry and morphology to the amosite mined in South Africa. These wastes are carried by lake currents southwest toward Duluth, where concentrations of such fibers in that city's drinking water can exceed one hundred million fibers per liter. The consequences of this public water supply contamination cannot be directly assessed, as no experimental data exist on the effects of ingested asbestos. However, the total number of fibers ingested over the years by Duluth residents approximates

that inhaled by workers in the amosite factory previously described. The finding of excess gastrointestinal cancer in this factory operation, as well as in other occupationally exposed asbestos groups, suggests the existence of a **potentially serious** health effect from such asbestiform mineral concentrations in public drinking water.

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Table 1

*
Expected and observed deaths among 689 asbestos
production and textile workers, Jan. 1, 1959 - Dec. 31, 1971

	<u>Observed deaths</u>	<u>Expected deaths</u>
Total cancer (all sites)	72	27.8
Cancer of lung, pleura, trachea, bronchus	35	8.4
Lung cancer	27	+
Pleural mesothelioma	8	+
Peritoneal mesothelioma	7	+
Cancer of stomach, colon and rectum	13	5.0
Cancer all other sites	17	14.4
Asbestosis	24	+
All other causes	103	106.5
Total deaths	199	134.3

+ United States data not available, but figure should be only slightly less than 8.4.

+
+ United States data not available, but these are rare causes of death in the general population.

* Expected deaths based upon United States mortality data from the U.S. National Office of Vital Statistics.

Table 2

Percent of deaths due to given
cause by estimated dust category

<u>Cause of Death</u>	<u>Dust Level</u>			
	<u>Min.</u>	<u>Mod.</u>	<u>High</u>	<u>Textile</u>
Asbestosis	5	13	20	39
Lung Cancer	16	10	16	9
Mesothelioma	6	13	8	5
G.I. Cancer	9	3	4	5
All Other Cancer	9	7	16	5
All Other Causes	55	54	36	39
All Cancer	41	33	44	29
No. of workers in each category	86	61	25	24

Expected* and observed deaths among 933** amosite asbestos factory workers
first employed 1941-45, and observed to 31 December 1971

	Before 1952		1952-61		1962-71		Total, 1942-71	
	Expected	Observed	Expected	Observed	Expected	Observed	Expected	Observed
Total deaths	69.98	88	108.27	146	121.24	250	299.49	484
Total cancer: all sites	9.81	15	18.72	44	21.63	84	50.16	143
Lung cancer	1.49	3	3.71	23	6.21	47	11.41	73
Pleural mesothelioma	n.a. ⁺	1	n.a.	0	n.a.	2	n.a.	3
Peritoneal mesothelioma	n.a.	0	n.a.	0	n.a.	4	n.a.	4
Cancer of stomach	1.45	3	1.84	4	1.29	4	4.58	11
Cancer of colon, rectum	1.56	2	2.61	5	2.88	8	7.05	15
Cancer of oesophagus	0.27	0	0.45	0	0.51	0	1.23	0
All other cancers	5.04	6	10.11	12	10.74	19	25.89	37
Asbestosis	n.a.	3	n.a.	7	n.a.	17	n.a.	27
All other causes	60.17	70	89.55	95	99.61	149	249.33	314

* Expected rates are based upon age-specific death rate data of the U.S. National Office of Vital Statistics from 1946-67. Rates were extrapolated for 1941-48 from rates for 1949-55, and for 1968-71 from rates for 1961-67.

** 933 men were employed. In 5 cases, ages were not known and these men have been excluded from these calculations. 877 men were traced to death or to 31 December 1971. 51 men were partially traced and remain in the calculations until lost to observation.

⁺ U.S. death rates not available, but these are rare causes of death in the general population.

Table 4

Expected and observed deaths of lung cancer among 876 amosite asbestos factory workers, first employed 1941-45, and observed to 31 December 1971.* Distribution by duration of employment

Duration of employment	Number of men	Person-years of observation	Deaths of Lung cancer		
			Expected ⁺	Observed	Ratio
< 3 months	256	5,869	3.55	13	3.66
3-11 months	294	6,158	3.58	15	4.19
1 + years	326	6,912	4.09	45	11.00
Total	876	18,939	11.22	73	6.51

* This table excludes 57 men. Ten died during first year of employment, 39 could not be traced after the first year, 7 had prior occupational exposure to asbestos and 1 had employment of uncertain duration. Seventeen men of the 876 were partially traced and remained in the calculations until lost to observation.

+ Expected rates are based upon age-specific death rate data of the U.S. National Office of Vital Statistics, 1949-67. Rates were extrapolated for 1941-48 from rates for 1949-55, and for 1968-71 from rates for 1961-67.

Expected and observed number of deaths among 623 New York-New Jersey
asbestos insulation workers 1 January 1943 - 31 December 1973
twenty or more years after onset of first exposure to asbestos

	<u>1943-1952</u>			<u>1953-1962</u>			<u>1963-1973</u>			<u>Total</u> <u>1943-1973</u>		
	<u>Exp.</u>	<u>Obs.</u>	<u>Ratio</u>	<u>Exp.</u>	<u>Obs.</u>	<u>Ratio</u>	<u>Exp.</u>	<u>Obs.</u>	<u>Ratio</u>	<u>Exp.</u>	<u>Obs.</u>	<u>Ratio</u>
<u>Total deaths - all causes</u>	88.22	82	0.94	111.05	170	1.53	101.38	191	1.88	300.65	444	1.48
<u>Cancer - all sites</u>	13.02	30	2.30	18.75	65	3.47	19.49	103	5.28	51.26	198	3.86
Lung cancer	1.83	13	7.10	4.20	29	6.90	5.65	47	8.32	11.68	89	7.62
Pleural mesothelioma	n.a.*	1	--	n.a.	2	--	n.a.	7	--	n.a.	10	--
Peritoneal mesothelioma	n.a.	1	--	n.a.	3	--	n.a.	21	--	n.a.	25	--
Cancer stomach	2.13	2	0.94	1.87	10	5.35	1.10	6	5.45	5.10	18	3.53
Cancer colon, rectum	2.22	7	3.15	2.74	9	3.28	2.54	6	2.36	7.50	22	2.93
<u>Asbestosis</u>	n.a.	1	--	n.a.	11	--	n.a.	25	--	n.a.	37	--
<u>All other causes</u>	75.20	52	0.69	92.30	94	1.02	81.89	63	0.77	249.39	209	0.84

632 members were on the union's rolls on 1 January 1943. Nine died before reaching 20 years from first employment. All others entered these calculations upon reaching the 20-years-from-onset-of-first-exposure point. Expected deaths are based upon white male age-specific death rate data of the U.S. National Office of Vital Statistics from 1949 - 1971. Rates were extrapolated for 1943 - 1948 from rates for 1949 - 1955, and for 1972 - 1973 from rates for 1967 - 1971.

* U.S. death rates not available, but these are rare causes of death in the general population.

Table 6

Summary of average asbestos air concentrations during insulation work

Research Group	Average Fiber Concentration	
	Light and Heavy Construction	Marine Work
Average concentrations of fibers longer than 5 evaluated using membrane filter techniques and phase contrast microscopy.		
Reitze-Nicholson, Mount Sinai	6.3	
Balzer-Cooper, U. of Calif.	2.7	6.6
Burgess-Lynch, Harvard		2.9
Harries, Great Britain		8.9
Average concentrations of all visible fibers counted using a konimeter and bright-field microscopy.		
Murphy, Harvard		8.0
Fleischer, U.S. Navy		30-40
Estimates of past exposure based on current membrane filter data.		
Nicholson, Mount Sinai	10-15	

Table 7

Expected and observed deaths among 17,800 asbestos insulation workers
in the United States and Canada, 1 January 1967 - 31 December 1972

	<u>Duration from onset of exposure</u>			
	<u>Less than 20 years</u>		<u>More than 20 years</u>	
	Expected*	Observed	Expected*	Observed
Total deaths - All causes	203.90	249	756.12	1109
Cancer - All sites	30.42	64	145.13	511
Lung cancer	8.40	28	47.47	247
Asbestosis	**	7	**	94
All other causes	173.48	178	610.99	504
Number of persons	12,681		5,119	

* Expected rates are based upon age-specific white male death rate data of the U.S. National Office of Vital Statistics. Rates for 1972 were extrapolated from rates from 1967 - 1971.

** U.S. rates are not available, but these are rare causes of death in the general population.

Table 8

Deaths from lung cancer and mesothelioma among 17,800 asbestos insulation workers
in the United States and Canada, 1 January 1967 - 31 December 1973;
relation to elapsed period from onset of exposure

Years from onset	Person-Years at risk	Lung cancer			Pleural and peritoneal mesothelioma
		Expected deaths *	Observed deaths	Ratio	Observed deaths **
< 10	24024	0.61	0	--	0
10 - 14	21284	2.20	6	2.73	0
15 - 19	25218	6.67	26	3.90	5
20 - 24	20344	11.38	42	3.69	7
25 - 29	12433	12.93	61	4.72	19
30 - 34	6969	10.36	73	7.05	17
35 - 39	3028	6.02	38	6.31	16
40 - 44	2306	5.58	29	5.20	15
45 - 49	1721	5.23	23	4.40	16
50 +	1845	6.01	23	3.83	8
Totals	119170	66.99	321	4.79	103

* Expected deaths are based upon age-specific white male death rate data for the U.S. National Office of Vital Statistics.

** Expected deaths from pleural and peritoneal mesothelioma are virtually 0.

Table 9

Expected and observed deaths of lung cancer among 17,800 U.S. and Canada asbestos insulation workers, 1 January 1967 - 31 December 1972; relation of cigarette smoking

	No. of Persons	Deaths from lung cancer		
		Expected	Observed	Ratio
Smoking habits not known	6144	16.76	94	5.4
History of cigarette smoking	9590	31.60	179	5.7
No history of cigarette smoking	2066	7.51	2	0.3

* Expected deaths based upon age-specific U.S. mortality rates for white males disregarding smoking. Lung cancer estimates based upon U.S. rates for cancer of lung, pleura, bronchus and trachea, categories 162 and 163 of the International Classification of Diseases and Causes of Deaths, 7th Revision.

Table 10

Total Employment on Construction and Repair of Naval and Cargo Vessels
1923 - 1944 (X 1000)

Date	Private Yards	Navy Yards	Total
Jan. 1923	68.5	22.4	90.9
Jan. 1925	56.4	21.0	77.4
Jan. 1927	66.2	20.9	87.1
Jan. 1929	53.8	23.0	76.8
Jan. 1931	55.6	20.5	76.1
Jan. 1933	32.9	21.6	54.5
Jan. 1935	44.1	18.8	62.9
Jan. 1937	62.0	33.3	95.3
Jan. 1939	61.7	39.9	101.6
Jan. 1940	79.4	57.8	137.2
Jan. 1941	147.7	107.8	255.5
Jan. 1942	396.0	192.7	588.7
Jan. 1943	1,184.3	294.6	1,478.9
Jan. 1944	1,357.2	326.0	1,683.2

Source: Bureau of Labor Statistics, Bulletin 824,
 "Wartime Employment, Production, and Conditions of Work
 in Shipyards," 1945.

Table 11

X-ray abnormalities among 210 family members of amosite asbestos workers

X-ray findings	Number of family members	
Pleural thickening only	25	(12%)
Pleural calcification only	9	(4.3%)
Pleural thickening and pleural calcification	34	(16%)
Irregular opacities only	25	(12%)
Irregular opacities, pleural thickening and/or pleural calcification	22	(10.6%)
TOTAL	81	(38.6%)

Table 12

X-ray abnormalities (1973 - 1974) among 210 family members
of amosite asbestos workers employed 1941 - 1954

	Total Examined	Total Abnormalities
Wives	63	33 (52.4%)
Daughters	73	13 (17.8%)
Sons	41	21 (51.2%)
Siblings	20	7 (35%)
Other	13	7 (53.7%)
TOTAL	210	81 (38.6%)

Figure 1

Relative Excess (Asbestos-Related) Risk
of Dying of Lung Cancer or Mesothelioma

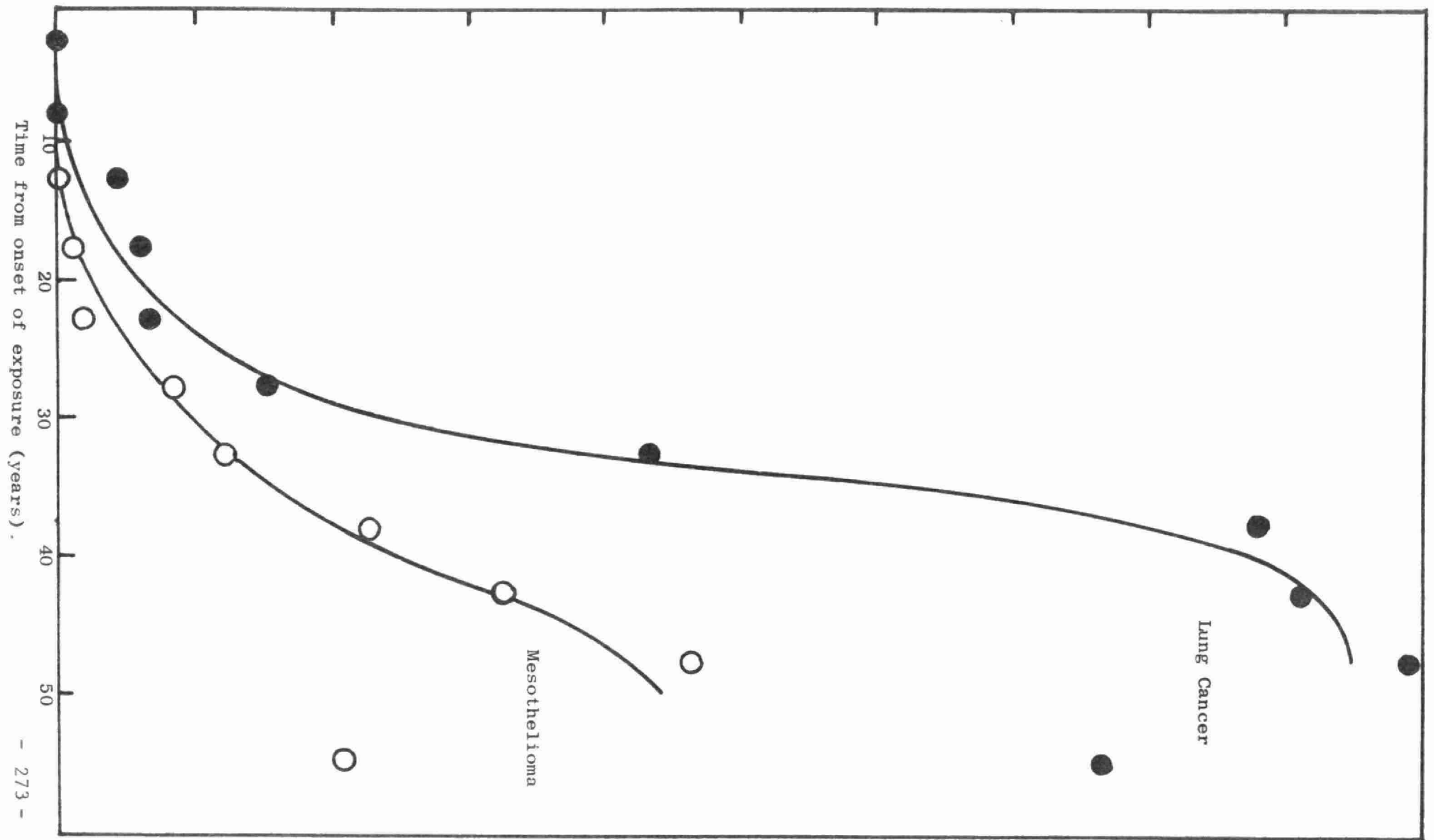
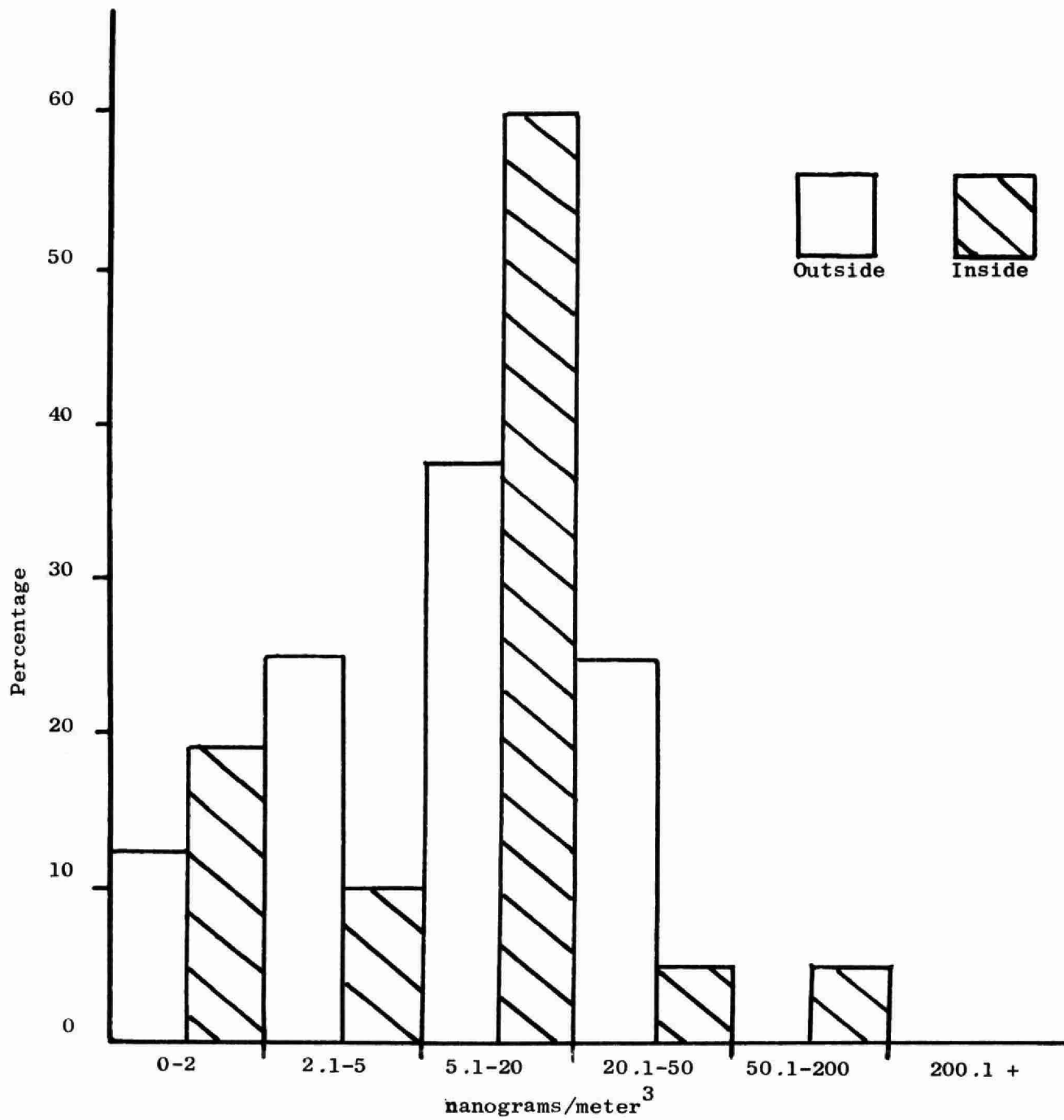
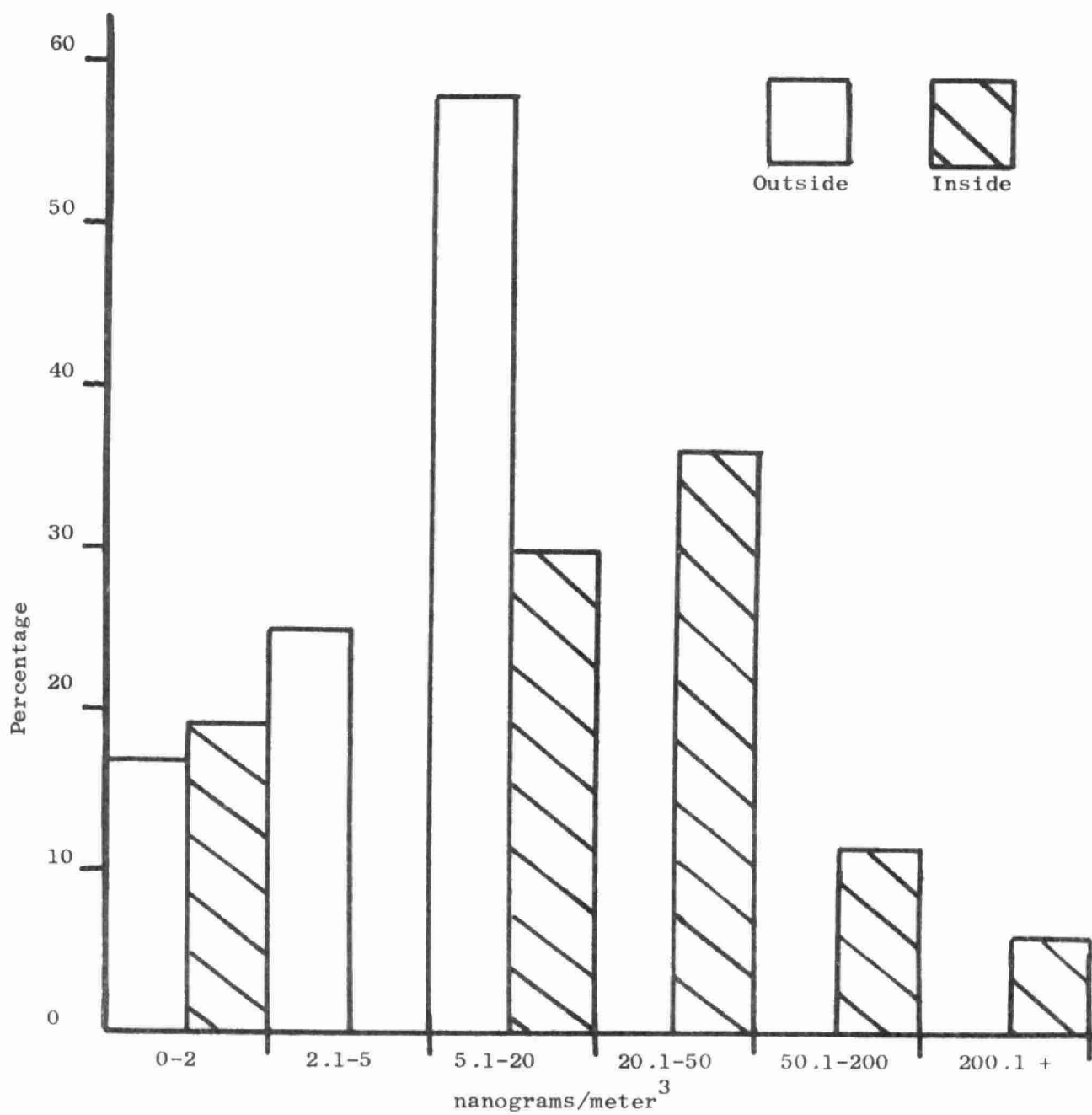


Figure 2



Percentage of Cementitious Spray Samples
Lying within a Specified Concentration Range

Figure 3



Percentage of Fibrous Spray Samples
Lying within a Specified Concentration Range

INSTRUMENTATION FOR ANALYSIS OF INDUSTRIAL EFFLUENTS

The paper discusses some of the functions of a modern environmental laboratory, with special emphasis on the application of modern analytical equipment to industrial wastes characterization.

Industrial effluents result from industries' activities in producing items necessary to the economy. Their comprehensive analysis is necessary because of the deleterious effects that certain components of some effluents may have on the environment.

Accompanying the recent development of ultra-sensitive analytical techniques has been the introduction of sophisticated automated and computerized machinery, so that today's environmental chemist can not only unravel the complex mixtures of industrial effluents and detect ultra-trace levels of specific components within them, but can do so at an unprecedentedly high rate of production.

Presented by

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INSTRUMENTATION FOR ANALYSIS OF INDUSTRIAL EFFLUENTS:

BY: J.N. BISHOP and P.L. DIOSADY

The purpose of this talk will be to introduce you to some of the functions of a modern environmental laboratory. Special emphasis will be placed upon the application of modern analytical instrumentation in identifying specific pollution problems, particularly those associated with industrial activities.

It is generally agreed that it is in everybody's interest that we live in a world which provides the highest quality of life. In order to accomplish this, we must attempt to reconcile our needs for goods - all of which are used to make our lives more comfortable and enjoyable - with the real need to conserve the natural resources of our province. Industry provides the goods required, by combining ingenuity with natural resources, and the environmental control agencies try to eliminate, or at least minimize, any harm that could come to the environment due to industrialization.

It has been argued that no pollution controls are necessary, since the industrial sector is quite capable of regulating itself. This may be the case with most industries,

but the tragic events in countries like Japan and Iraq indicate that some control is necessary. On the other hand, it can be argued that Industry should be forced to emit absolutely no effluents and that compounds even remotely possible to contain dangerous compounds must not be released. This is the "zero" discharge concept, and is one that would be extremely difficult to enforce or monitor.

About 20 years ago, there existed a stalemate between industry and the environmentalists. This impasse was broken by two large scale events that occurred at approximately the same time. First, the environment began to deteriorate so rapidly that even the most profit-conscious industries were alarmed. Catastrophes occurred, involving entire species of animals, tracts of water and land, and even human beings (as in Minamata, Japan). Second, the analytical tools required to detect, quantitate and characterize the complex industrial effluents underwent remarkable development.

At Industrial Wastes Conferences in the past, Ontario Ministry of the Environment Laboratory personnel have outlined the tools and techniques used in this complex job, and this paper will cover the instrumentation added in the past few years. Because of the great number of instruments and techniques involved, the nature of this talk will be very broad in scope. It is hoped that you will be made aware of what the instruments can do, rather than how they do it, and no one technique will be dealt

with in great detail.

First, I'd like to briefly deal with the history of the laboratory's development. The laboratory originally operated with rather primitive facilities (SLIDE 1). The next stage was the O.W.R.C. laboratory, opened in 1960, (SLIDE 2) with about 100 scientists and technicians. In 1974 the laboratory expansion project was completed, at a cost of \$11 million. The laboratory is staffed with 200 scientists, bacteriologists, technicians, and support personnel. These facilities constitute the largest and best equipped environmental analytical laboratories in Canada (SLIDES 3 and 4). All of the slides shown in this paper depict equipment in use in the M.O.E. laboratories.

The general progress of the laboratory is shown in the next few slides.

SLIDE 5 illustrates the development of the M.O.E. laboratory as an environmental control agency in Ontario.

SLIDE 6 shows the enormous increase in tests completed as the years progress. We now do well over 1 million tests per year, ranging from very simple to extremely complex tests on a wide variety of types of samples. It can also be seen from this diagram that the number of people employed has not increased as rapidly as the number of

of tests performed, an indication of the increased productivity and efficiency in the Laboratory. (Fig. 1) SLIDE 7 shows the way in which instrumentation has changed, from the early classical systems through instrumental techniques, to remote monitors, computerized systems, and diagnostic equipment such as mass spectrometers and emission spectrographs.

In order to cope with this tremendous work input, it was necessary to automate as many functions as possible. Most tests that involve routine chemistry and measurement have been automated. Automated titralizers, and Technicon autoanalysers are useful for high speed, automatic analysis for pH, hardness, total and soluble phosphate, ammonia, nitrogen, and other nutrients. These automated systems are capable of performing 40 to 60 tests per hour, unattended, at the ppb to ppm range for many parameters.

However, a good deal of non-instrumented classical chemistry is still performed. Classical tests such as the COD, or Chemical Oxygen Demand, boron, and others are performed, and custom-made sample preparations are often necessary in order to handle the wide variety of industrial samples received in the laboratory. Techniques such as digestion (with at least 10 acid-oxidant combinations) distillation, fraction collection and so on are tailor-made to meet the specific demands of the wide variety of Industrial effluents. However, even in sample preparation, sophisticated equipment is being developed. The Low Temperature Asher, which uses an oxygen plasma (consisting of O_3) to ash organic compounds at low temperatures is used increasingly. In this way, leaves,

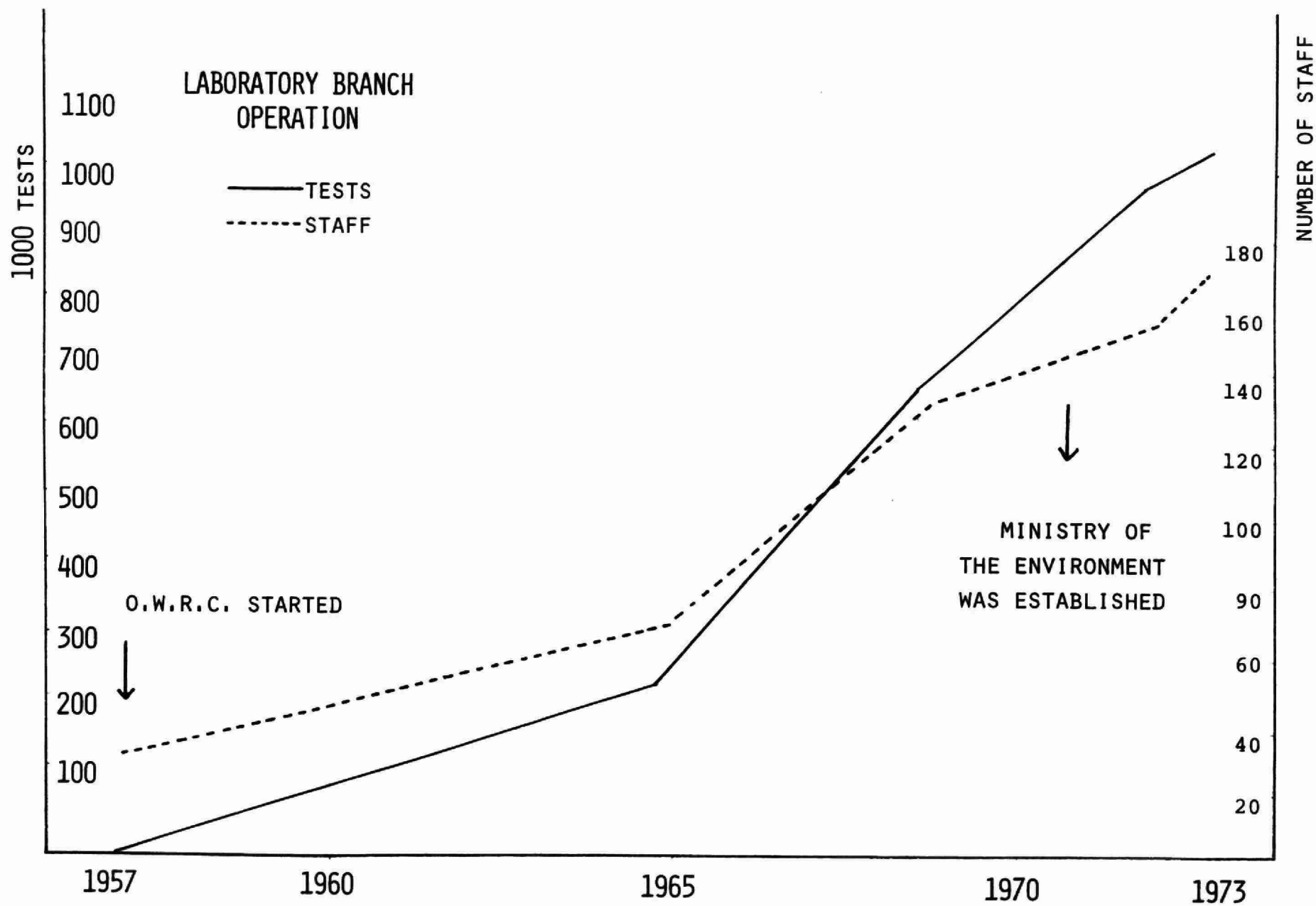


Figure 1: Increased Productivity in the M.O.E. Laboratory.

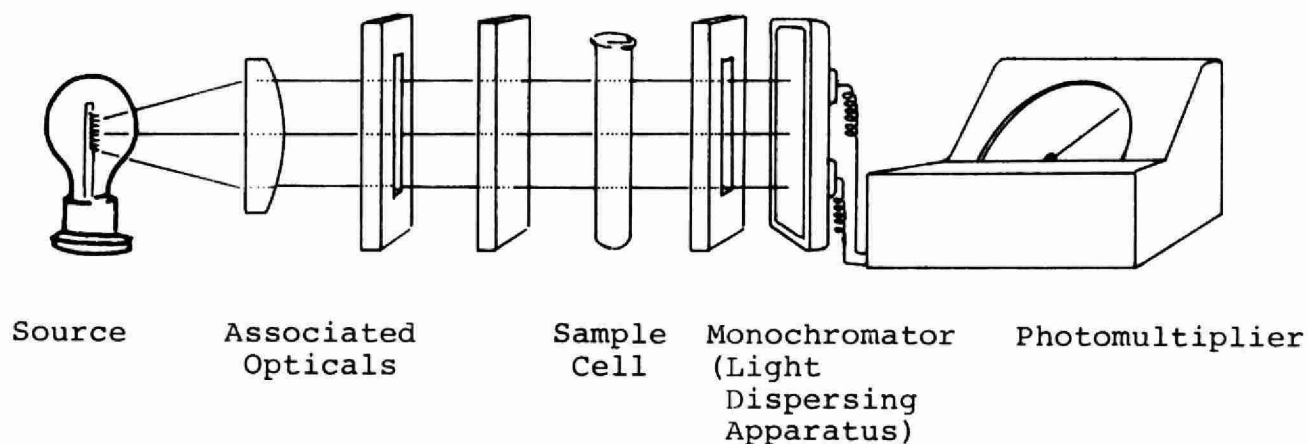
fish, aquatic biota, plastics, and so on can be oxidized - destroyed - at temperatures less than 105° , thereby minimizing the possibility of losses of metals by volatilization.

I would now like to discuss the analytical instruments used to determine individual constituents at trace levels. Following this, I will deal with the analytical instruments used in diagnostic applications; that is, where the specific pollutant is not known but must be identified and if possible quantitated.

I. The next series of topics deal with some of the former types of equipment - those used for specific, individual analysis.

1) COLORIMETRY (UV-VISIBLE SPECTROPHOTOMETRY)

Figure 2: Optical Schematic of a Typical Spectrophotometer.



The diagram shows a general outline of a typical spectrophotometer. A light beam from a polychromatic source is passed through a cuvette containing the sample solution and then into a monochromator and detector. The instrument is usually equipped with an automatic wavelength scanning

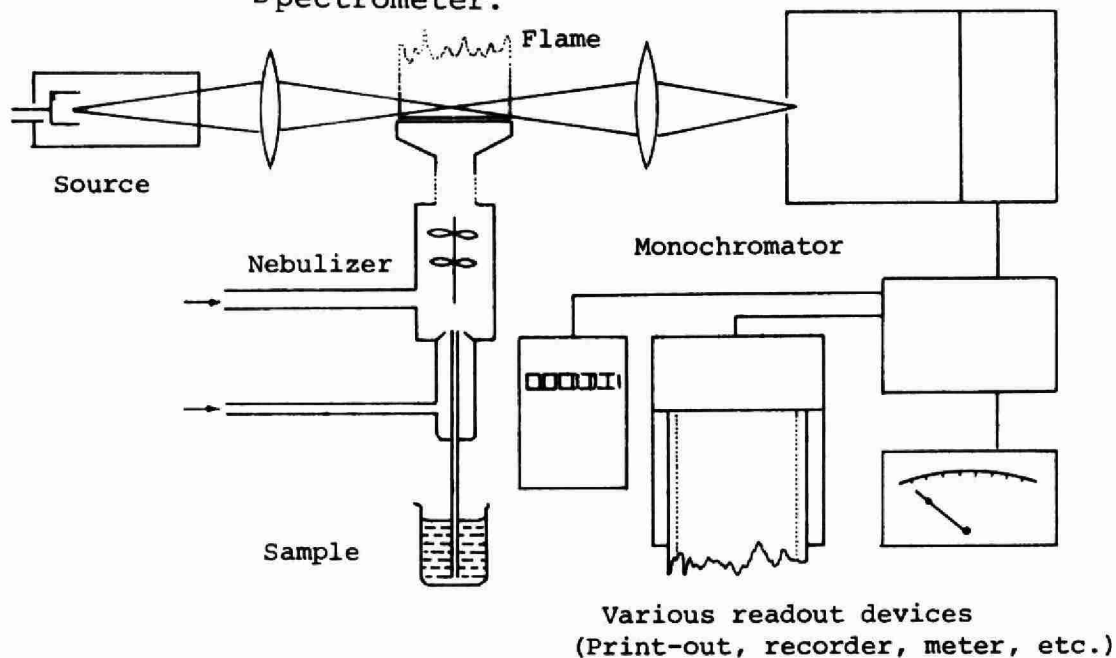
facility so that it is possible to obtain a graph of absorbance versus wavelength.

The molecules of the test solution absorb light of certain energy which is characteristic of the complex. The magnitude of the absorbance is proportional to the concentration of the complex.

2) ATOMIC ABSORPTION SPECTROPHOTOMETRY

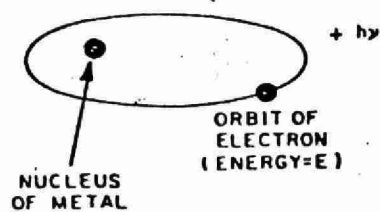
The light from the source is a photometer (Figure 2) can be absorbed by molecules in solution, as is the case in colorimetry, or it can be absorbed by atoms in a flame, as in atomic absorption spectrophotometry (AAS).

Figure 3: Schematic Diagram of an Atomic Absorption Spectrometer.



AAS is a rapid, relatively interference free technique used for the detection and quantitative analysis of trace amounts of heavy metals in solution. (Figure 3).

A hollow cathode lamp which emits the atomic spectrum of a particular element, (zinc for example) is focused on a monochromator and photomultiplier tube. The detection



EMISSION | ABSORPTION

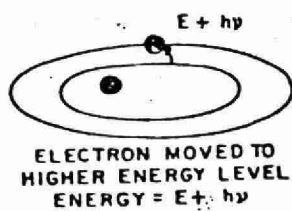


FIGURE 4:

The Relationship between Atomic-Absorption and Atomic-Emission Spectroscopy.

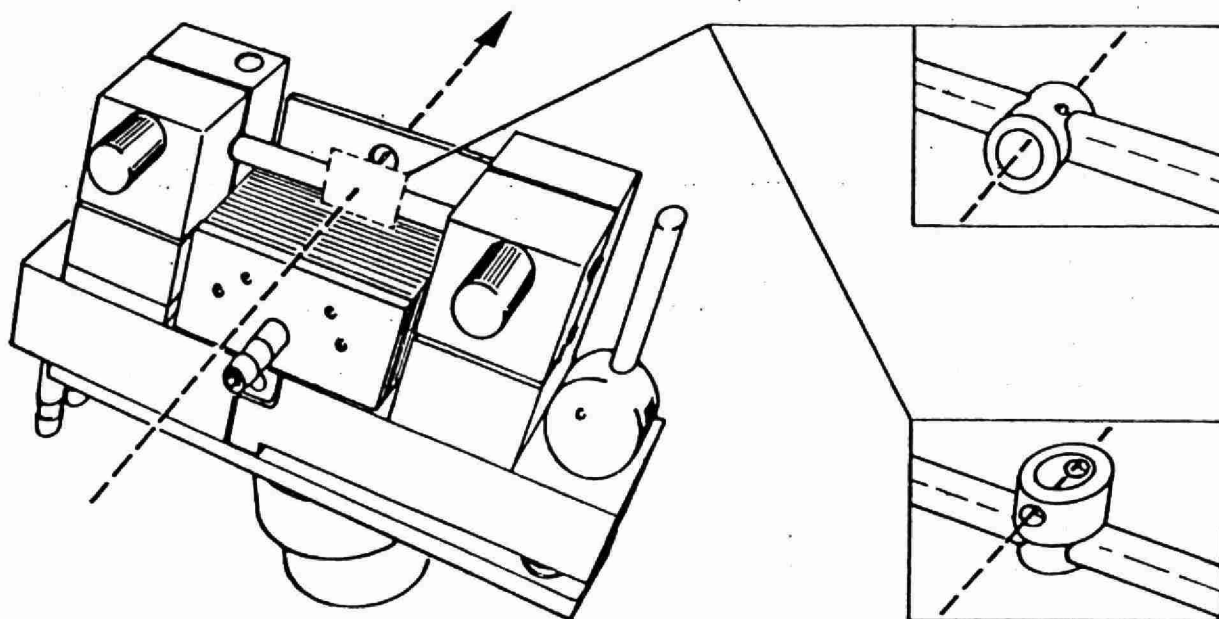


Figure 5: Carbon Rod and Cup (Flameless AAS)

system is set to respond to a particular line of the atomic spectrum of zinc. A burner nebulizer system is placed such that the light from the hollow cathode passes through the flame. The nebulizer aspirates the solution containing the element to be analyzed into the flame as a very fine aerosol. In the flame, the metal ions are reduced to atoms. They can absorb or emit energy (Figure 4). Because of the very specific energy levels associated with atoms and atomic spectra, the zinc atoms and (in theory) only the zinc atoms absorb energy from the hollow cathode. This absorption is detected as an absorbance which is proportional to the concentration of zinc ions in the original solution. This technique can be applied to over 70 elements.

In the Air Quality and ITC Sections, the AAS is used extensively, and for some elements, automated systems are in use. Arsenic and selenium are determined by automated AAS, where Technicon pumps mix samples with a powerful reducing agent (sodium borohydride) to form volatile hydrides. These gases are swept into a heated cell in the light path of an AAS unit, where the gases break down to their constituent atoms. The As and Se atoms, while resident in the cell, absorb some of the light being emitted by the As and Se hollow cathode sources.

3) FLAMELESS AAS

FAAS is a relatively new technique which is applied to the determination of very low levels of metals. The same principles are involved as for AAS, except that atomization is not accomplished by a flame. Rather, the sample is

introduced into a resistively heated furnace which is usually constructed of carbon. The sample is then dried ($\sim 125^{\circ}\text{C}$), ashed ($\sim 600^{\circ}\text{C}$), and atomized ($\sim 3000^{\circ}\text{C}$). The red hot furnace in an inert atmosphere serves as a reducing medium for the metal ions. Since the event occurs quickly and the atoms are retained in the tube furnace for some time, sensitivities are $\sim 100\text{X}$ better than conventional flame techniques. (Figure 5).

4) POLAROGRAPHY

The next sections deal with electroanalysis, a technique that was very popular several decades ago, lost favor, and has seen a remarkable renewal of application in the past 5 years.

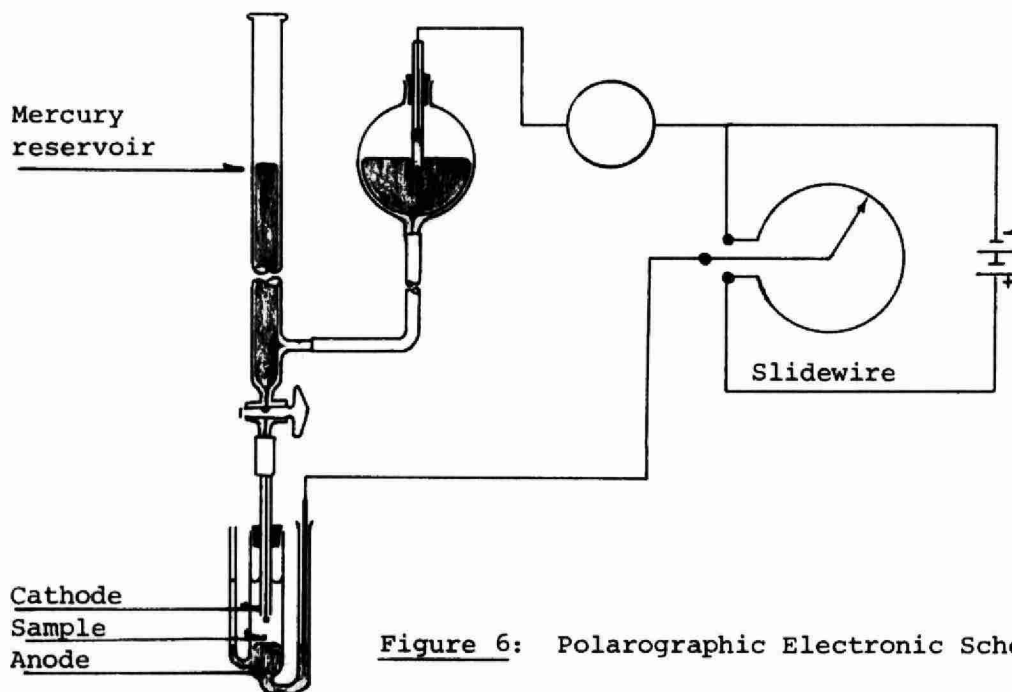


Figure 6: Polarographic Electronic Schematic

A polarograph determines the concentration of reducible ions in a solution by measuring the current which flows when the ions are reduced electrolytically. A variable voltage is applied across the cell in which an aliquot

of the aqueous sample is contained with a suitable supporting electrolyte. The cathode is formed by a drop of mercury which drips off a capillary immersed in the solution. The total current variation is proportional to the concentration of metal ions in solution. The half-wave potential is characteristic of the type of metal ions being reduced.

5) ANODIC STRIPPING VOLTAMMETRY (ASV)

ASV is used for the determination of very low levels (1 ppb or less) of certain metals, particularly Zn, Cu, Pb and Cd with high accuracy and precision. Because of the nature of the technique it is possible to distinguish between simply dissolved or "free" ions and ions complexed by naturally occurring or man-made ligands.

In ASV a constant reducing potential is applied to a mercury electrode for a controlled time period. During this time, ions are reduced to atoms which form a dilute solution in the mercury (amalgam). The potential of the drop is then altered at a constant rate to more positive (oxidizing) potentials. Each type of metal atom has a specific oxidation potential so that the individual types of atom are oxidized and released into the solution at different times. These oxidations generate current flows which are recorded on a current versus time basis.

The plating out process effectively concentrates the metal ions and since the release on oxidation is rapid, the technique is extremely sensitive. (Figure 7).

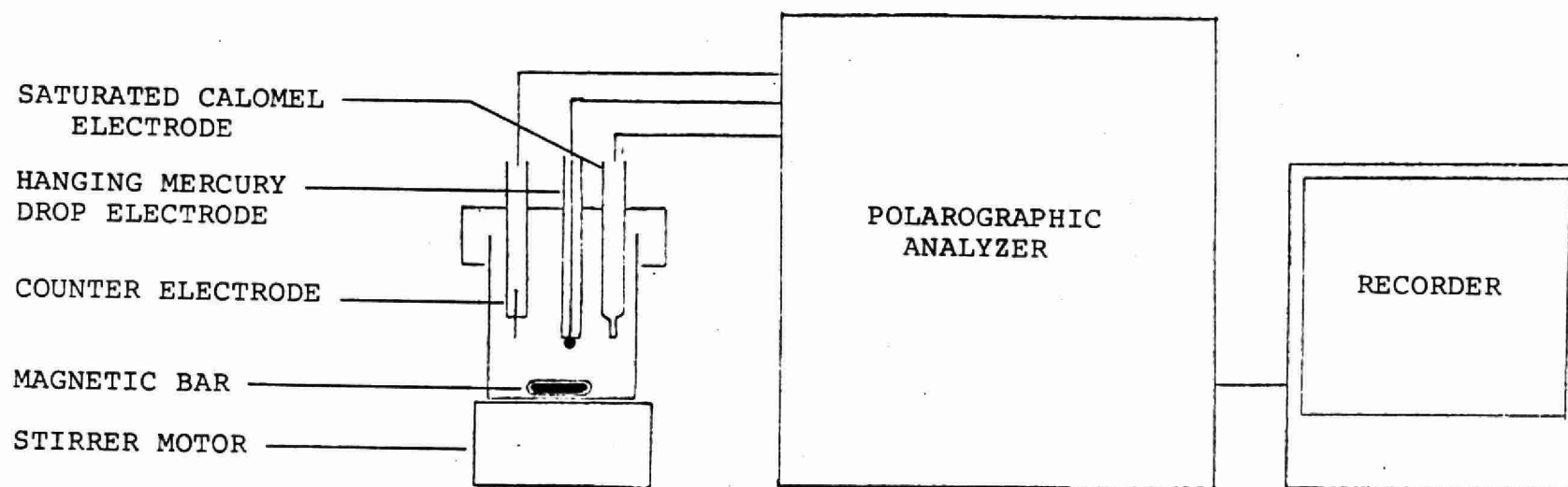


Figure 7: ANODIC STRIPPING VOLTAMMETRY SYSTEM

6) GAS CHROMATOGRAPHY

Up to now, most of the techniques discussed were concerned with inorganic analyses. However, the work of the laboratory often requires highly sensitive, precise organic analyses as well. The backbone of this effort is the gas chromatograph. Gas chromatography is used for qualitative and quantitative analysis of most materials having a vapor pressure of above 1 mm at 250°C (B.P. 500°C). This covers most gases, liquids and low-melting organic solids. Polymeric materials and high-melting solids may also be analyzed by gas chromatography through their degradation products. This technique may be applied to complex mixtures as well as to trace impurities. The sample vapors are carried through a fractionating column in a carrier gas stream. The components are separated on this column because each sample component has a different affinity for the column material. Various types of detectors measure the concentration which is read out by a computer, integrator, or strip chart recorder.

Gas chromatography is automated in many of its applications at the laboratory. This recent development not only increases efficient use of manpower, but it provides superior precision (due to the reproducibility of sample injection) compared to normal operations. (Figure 8).

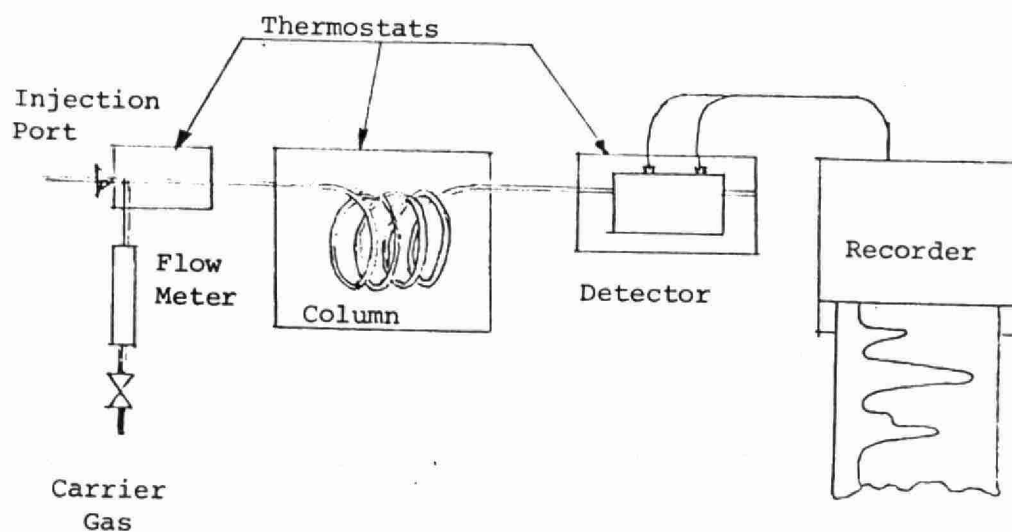


Figure 8: Scheme of a Gas Chromatograph

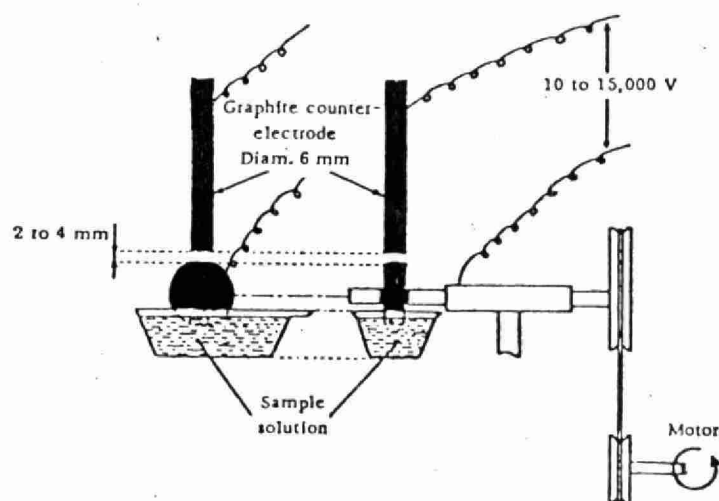


FIGURE 13: Spark spectrography with the rotating electrode.

7) HIGH PRESSURE (OR PERFORMANCE) LIQUID CHROMATOGRAPHY

High speed liquid chromatography is a high resolution separation technique used for the qualitative and quantitative analysis of both organic and inorganic compounds in solution. It is particularly useful for the separation and analysis of thermally unstable materials, and compounds with vapor pressures too low to be analyzed by gas chromatography.

In liquid chromatography the constituents of a solution are separated in the chromatographic column, which is a tubing packed with a solid adsorbent, an ion exchange resin or a liquid coated on a solid support. These packing materials constitute the stationary phase. The sample is carried into and through the column by a solvent, which is called the mobile phase. The sample components are separated due to their differing affinities for the mobile and stationary phases and are detected and quantitated as they emerge from the column by one of their specific physical properties (UV absorption, refractive index, conductivity, etc.) (Figure 10).

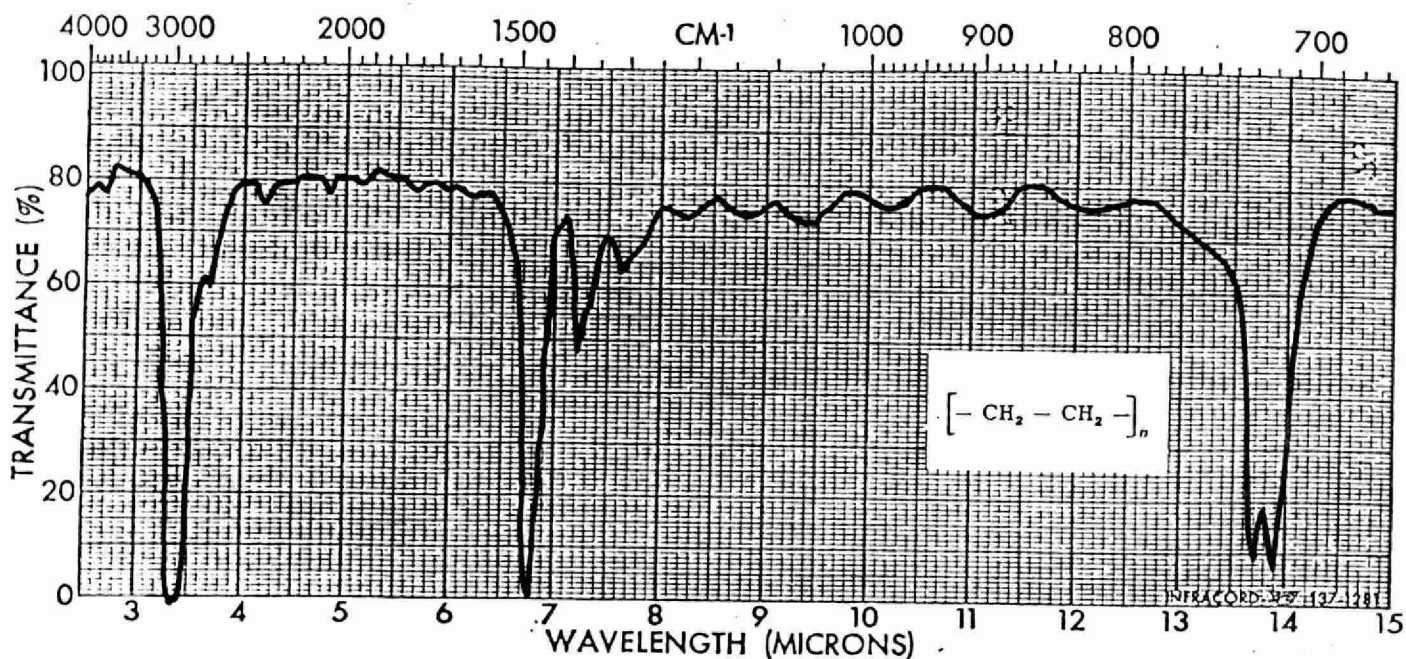


Figure 9: Infrared Spectrum of Polyethylene Film.

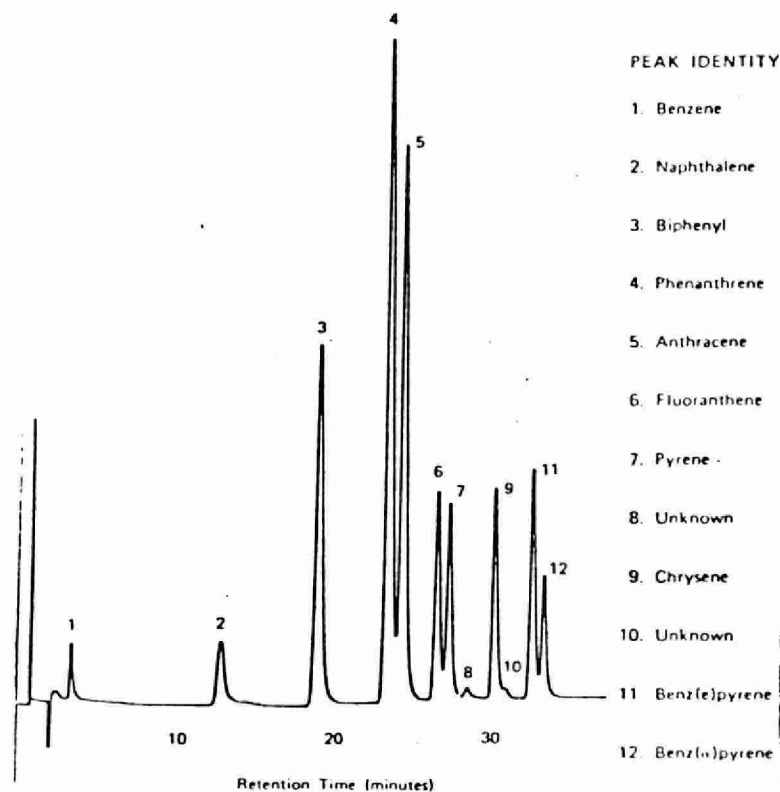


Figure 10: Separation of Chromatic Compounds by High Pressure Liquid Chromatograph.

8) PROTON NUCLEAR MAGNETIC RESONANCE SPECTROMETRY

This is a spectroscopic method which, by measuring the amount of energy required to change the nuclear spin of a proton, indicates the molecular environment of a proton, and its interrelationship with other protons in a molecule. It is used in the determination of the structure of organic (and some inorganic) molecules. Along with other methods the OTC section will use it to identify organic pollutants in industrial effluents.

The sample material is dissolved in an appropriate solvent and placed in a special sample tube which is suspended in a magnetic field. The proton of each hydrogen nucleus acts as a small magnet and its effect is measured by means of a superimposed radio frequency and recorded. The patterns of peaks ("signals") which results is called the NMR spectrum. The position of each signal on the graph is determined by the environment of the specific hydrogen atom responsible for the signal. The area under each peak is directly proportional to the number of each type of proton. The multiplicity of each peak indicates the number of hydrogen atoms on adjacent carbon atoms.

II. DIAGNOSTIC EQUIPMENT

Thus far, the topics have all dealt with instruments generally designed for specific application to one element or compound at a time.

1) OPTICAL MICROSCOPY

The simplest, and perhaps the most widely used diagnostic tool is the optical microscope. It is used extensively in microbiological applications as well as in identification of unknown materials in chemical samples.

2) INFRA-RED SPECTROSCOPY

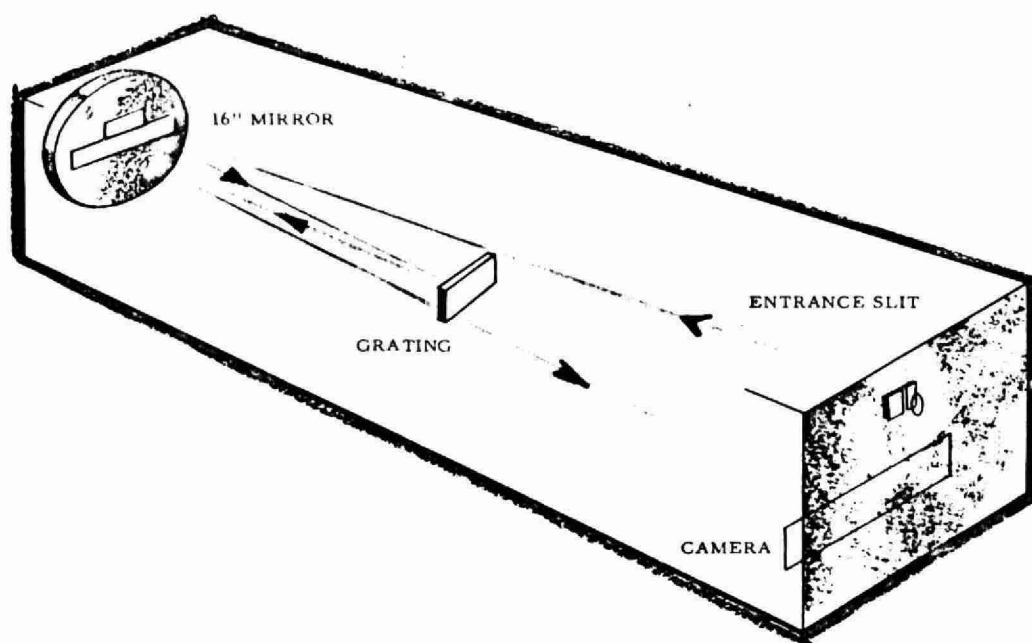
The IR system is basically the same as that described for a typical spectrometer (Figure 2). In the M.O.E. laboratories, the IR is generally used for analyzing samples arising from oil pollution. Oil pollution on the Great Lakes, for example, has been a problem in the past, but strict legislation, steeper fines, and increased cooperation from offenders, are gradually reducing the problem. In the U.S., however, it is estimated that there are 10,000 oil spills per year, involving the loss of 500,000 barrels of oil into water. This information leads one to conclude that the analytical techniques used to track down the sources of such losses will not decline in usefulness of application.

IR spectroscopy operates on the following principles. All compounds absorb infrared radiation selectively with respect to wavelength. All atoms in a molecule are in continuous motion and are vibrating at definite frequencies specific to the molecular structure. Two conditions must be met before a molecule can absorb infrared radiation. First, there must be a change in the dipole moment and second, the molecular vibration frequency must be identical to that of the

molecular vibrations, then the radiation passes through the molecule without loss of energy. Consequently, when infrared energy of successive wavelengths is passed through a molecule and the fraction of transmitted energy is plotted against the frequency of wavelength, the result is an infrared absorption spectrum. (Figure 9). Thus, a "fingerprint" of the compounds in the sample is obtained, to be compared to "fingerprints" or spectra, of pure compounds analyzed separately.

3) EMISSION SPECTROGRAPHY

Figure 11: Schematic of Optical System for an Emission Spectrograph.



The emission spectrograph determines concurrently almost all the elements in any type of environmental sample. Its sensitivity is limited to the ppm range, however by preconcentration or using special techniques (plasma, laser) sensitivities several orders of magnitude better may be achieved. Used in the photographic mode, a complete elemental distribution may be obtained, while the computer-operated direct reader can produce quantitative results for more than thirty elements on any type of environmental sample in a few minutes. It also reveals the presence of unsuspected elements, which can then be determined by other techniques.

The two modes of operation are worth stressing at this stage:

a) In its photographic mode of operation, spectra of all the elements existing in a sample are recorded on two 12 inch (50 cm in total) photographic plates for analysis and/or as a reference record.

b) As a direct-reading spectrometer the system contains 47 photomultiplier tubes in its direct reading attachment. The available 47 channels are dedicated to monitoring spectral lines of 36 elements:

Ag, Al, As, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, Ge, Hg, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Pd, Sb, Se, Sn, Si, Sr, Ti, Te, Tl, V, Zn, Zr

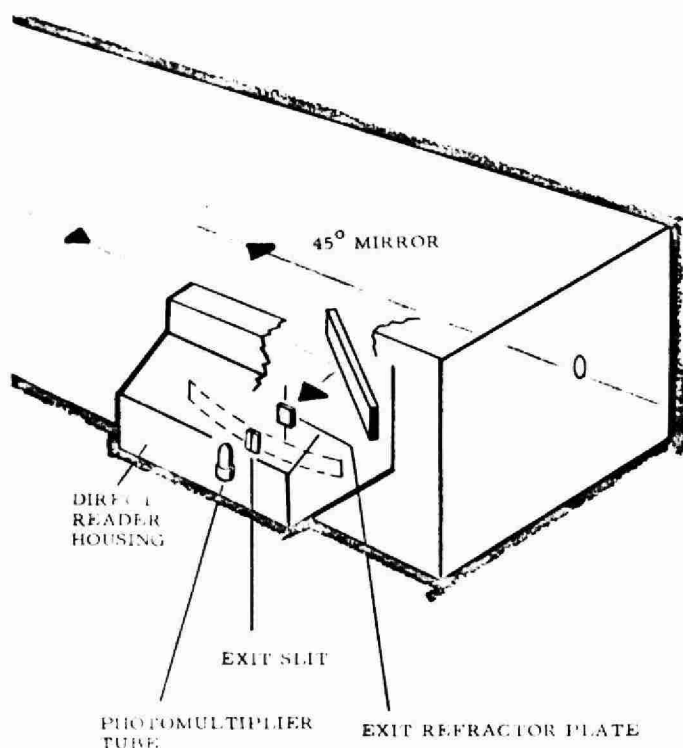
at high sensitivity while 6 channels are adjusted to accept less sensitive lines for high concentrations of Ca, Si, Cu, Fe, Pb and Mg.

Operation of all the channels and the excitation source is under the complete control of a dedicated PdP-8 computer with a "random access" extended memory. The computer is

calibrated and standardized to store the calibration curves for various matrices in its memory. The photoelectric currents from a preselected number or all of the channels are referred to such curves and the computer will print out the analytical results either in absolute intensities, intensity ratios and/or concentrations in ppm or percentages. With the computer's extended memory, the spectrochemical controller can be calibrated to store a large number of analytical curves of elements in various matrices. (Figures 11, 12, and 13).

The analytical results are printed out by the aid of a dedicated teleprinter.

Figure 12: Optical path for Direct Reader Attachment to Emission Spectrograph.



4) TRANSMISSION ELECTRON MICROSCOPE

The TEM with high resolution and magnification may be used to identify particles in the submicron range. Particles above 1 micron in diameter can be accurately measured and - through their diffraction pattern - identified. This technique is especially useful in the analysis of non-homogenous materials, such as air particulates, sediments, plant and animal tissue. Identification of bacteria, viruses, asbestos and other mineral fibres can be performed with this system. (Figure 14).

5) SCANNING ELECTRON MICROSCOPE

The SEM provides details of surface characteristics of particulate material, making it possible to identify these materials based on morphological characteristics and surface pattern. However, combined with X-ray analysis both in energy dispersive and wave length dispersive modes it is possible to confirm the finding by morphological characteristics, showing the presence of major constituent elements or scanning through the complete elemental composition of the particle under examination. See Figure 15. Using a computer for the X-ray analytical system of the electron microscope, highly accurate analysis may be obtained in a few minutes. The actual time consuming step in electron microscopic analysis is the sample preparation. (Figures 14, 15, and 16).

6) MASS SPECTROMETER

The mass spectrometer is a very powerful instrument, as it is capable of identifying trace quantities of volatile organics. Based on the separation of ionic fragments

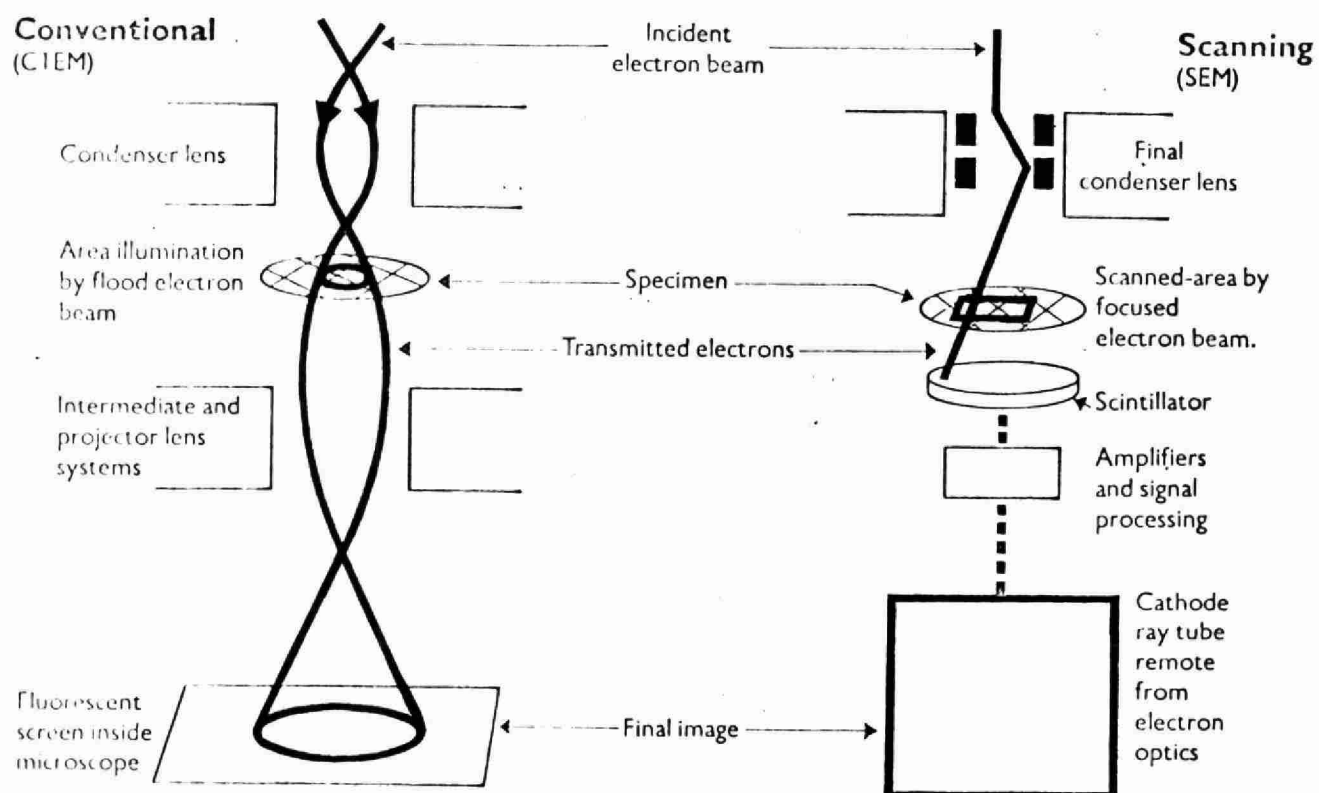
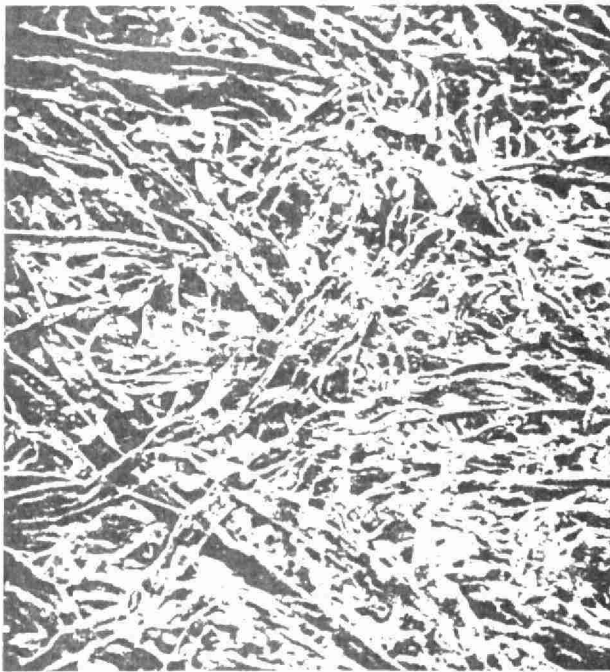


Figure 14: Principle of Transmission and Scanning Electron Microscope.

SCANNING ELECTRON MICROSCOPE



500X



1000X



2000X



2500X

Figure 16. Photographic recordings of a paper surface at various magnifications.

produced by bombardment with high speed electrons in an electromagnetic field, detailed information may be obtained on the nature of the compound examined. Combined with gas chromatograph and computerized read-out this instrument is useful in detecting and identifying general environmental pollutants, such as pesticide residues, PCBs, phthalates, chlorinated hydrocarbons, various carcinogens, odour causing substances, etc. (Figure 17).

The mass spectrum can be described as a fingerprint characteristic of the particular compound. Identification can be obtained by matching the spectrum of a sample with the spectrum of a standard. With high resolution spectra, the elemental composition and the empirical formula of the unknown pollutant can be determined. Another method of identification is through a chemists interpretation of the spectrum.

In general, it has been shown that the diagnostic instruments work best when various physical methods are combined and the operation is aided by a computer. Thus the spectrograph photographic and computerized direct reader combination, the Electron Microscope, X-Ray - computer system and the GC/MS - computer systems are among the most powerful techniques available today for elemental analysis, compound and particle identification.

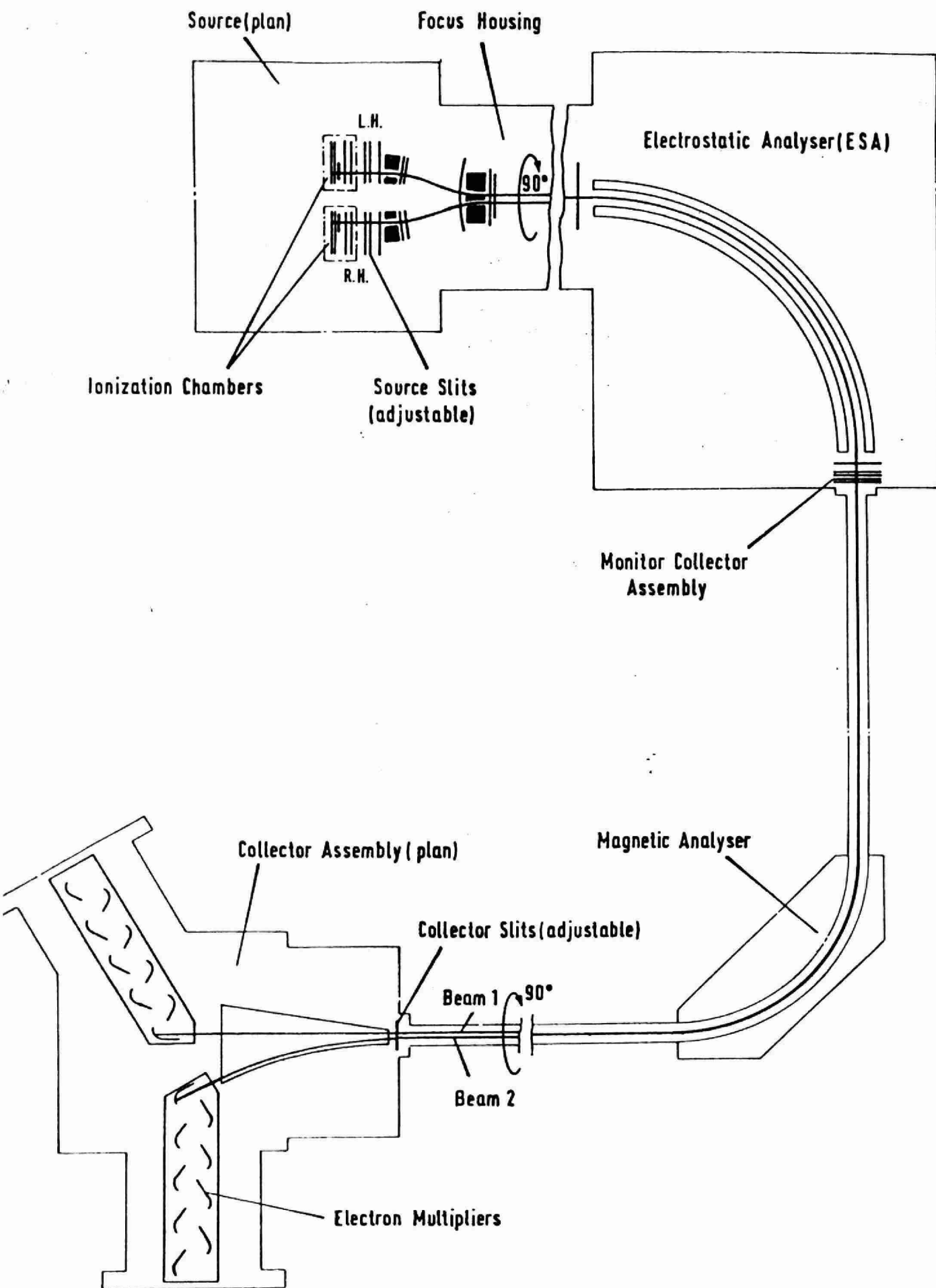


Figure 17: Double Beam Mass Spectrometer: Principles of Operation.

III. CONCLUSION

The next slide shows a scene very similar to that used in the opening of this talk. We have come full circle, from showing the existence of a problem, through a survey of some of the tools used to help solve the problem, and finally to a picture of continuing environmental pollution.

However, there is a subtle difference in this picture, which depicts a mine tailings dump in the Sudbury region. Today, on many such tailing dumps, there are growing, living coverings of grass, sphagnum moss, or bush, where yesterday there would only have been barren, desolate rock. This type of progress can also be seen in certain waters around the Province, such as the Credit River - once described as a rat's paradise due to the thick, polluted water - where coho salmon are caught in increasing numbers each year. Or parts of Lake Erie - so often referred to as a "dead" lake - where record catches of walleye and perch were made last year. Through the continuing efforts of Industry thoroughly committed to preserving the water and air they use, and through the regulatory efforts of such agencies as the Ministry of the Environment, this steady improvement of the environment will be assured for the people of Ontario.

In closing, I'd like to remind this heavily engineering-oriented gathering of the role of the analytical chemist. It is only with reliable data that an engineer can efficiently operate and make sound decisions, and it is increasingly apparent that the chemist can produce this kind of data, as well as interpret it and effectively help in the decision-making process, only if he has available the type of sophisticated equipment outlined in this paper. Without this data, which provides the foundation for environmental action, it would be impossible to evaluate

deterioration or improvement in the environment. With it, the scientist will be able to provide more sensitive and reliable data, and more of this data; it remains up to you - the engineer - to use this information to its best advantage.

ANALYSIS OF LEACHATES FROM INDUSTRIAL SOLID WASTES

Various procedures have been used by the Ontario Ministry of the Environment Laboratories to assess the pollutant potential of industrial solid wastes. Attempts have been made to simulate field conditions by leaching relatively undisturbed solid waste in columns and also to develop a rapid test using a wrist-action shaker. Several extractants have been used including simulated rain water, distilled water, ammonium acetate, acetic and sulphuric acids.

Some data is given for leaching tests on various types of industrial solid wastes.

Factors affecting leachate production, such as infiltration rate, surface area and chemical composition and interactions, are discussed.

by

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Analysis of Leachate from
Industrial Solid Waste Disposal Sites

F. C. Darcel

Ontario Ministry of the Environment,
Central Laboratory

There is an increasing awareness of environmental hazards associated with the disposal of industrial solid wastes. Several options may be available for method of disposal. Dumping at a landfill site is usually the cheapest, providing the material is in suitable form, possibly through pre-treatment.

Instances have been recorded of ground water contamination by industrial wastes containing chromium (6, 9, 49), cadmium (26), lead and mercury (8, 39).

In Minnesota, lead arsenate buried thirty years previously, resulted in lead poisoning in 1972. Similarly, arsenic wastes dumped over a 20 year period lead to 175 mg/l arsenic in ground water (46). In Ontario, elevated levels are being monitored in the Moira River (about 1 ppm) originating from abandoned mine tailings about 20 years ago.

High boron concentration (67 mg/l) was found in a small stream close to a private industrial dump close to the St. Lawrence River near Brockville.

Other recent instances in Ontario include the contamination of ground water by lead and sulphuric acid from a storage battery reclamation plant in Toronto and by vanadium, molybdenum, arsenic, sulphate and fluoride from a metal alloy processor in Ottawa. Iron (up to

240 mg/l) has been found in wells in Trenton. Chromium (30 mg/l) was present in spring water used for livestock and the source was traced to chrome plating waste illegally dumped in an abandoned gravel pit. High chloride (over 1000 mg/l) was found in wells in the vicinity of salt dumped in the Ottawa area.

Contamination of lake waters by acid, heavy metals, sulphate and ammonia from acid mine wastes in the Manitouwadge area of Ontario was described by German (13) at the last Industrial Waste Conference. High concentrations of nickel (3 mg/l) and aluminum (6 mg/l) were detected in wells in the Sudbury area.

Stored industrial wastes can also lead directly to air pollution. An interesting case followed by the Ministry was the generation of the highly poisonous gas phosphine (PH_3) from a slag stored (and even spread on the grass) on the grounds of a small aluminum foundry in Toronto.

Many industrial wastes are organic. Assessment is normally by general tests on leachate such as BOD, COD and phenols. An example is the very high BOD and COD associated with sugar refinery waste previously dumped along the Toronto water front.

Pesticides and chlorinated hydrocarbons can also cause serious environmental problems. Polychlorinated biphenols were detected in an auto manufac-

turing filter pre-coat waste by the Ministry of the Environment.

Potential hazards from different types of manufacturing operations have been described (46). The more hazardous inorganic substances are arsenic, cadmium, chromium, copper, cyanide, lead, mercury and selenium.

A much larger quantity of municipal refuse than industrial wastes has to be disposed of and the leachate from the former can also cause serious environmental problems. Industrial leachates should, therefore, be viewed in the perspective of municipal leachate.

Considerable experimental work has been conducted on the leaching of municipal refuse and mixtures of soil and sewage sludge in the field and laboratory, often for extended periods. In contrast, there is little literature on small scale leaching tests for industrial waste, possibly because of the wide range of composition and local rather than general problem situations. Recently, however, interest has developed in leaching studies on fly ash from thermal power generating stations with a view to finding uses for this abundant waste product.

Since some solid or semi-solid industrial wastes may be mixed with municipal wastes and soil, and to better understand some of the problems and complexities of leaching tests, it is useful to consider chemical and biological interactions within the site.

COMPOSITION OF LEACHATE AND GAS

An excellent paper on the high pollutant potential of leachate from sanitary landfills was given by Rovers, Nunan and Farquhar at the 21st Ontario Industrial Waste Conference (35).

It was commented at the International Round Table Conference on Leachate Analysis, Vancouver, B.C., April, 1975 (10) that there was high toxicity of leachate to fish, especially so if it was acidic. Toxicity occurred at .062% by volume (96 hr TL_M).

Some heavy metals appear in leachate, sometimes in fluctuating concentration, as for copper. Usually, there is a delay before their appearance as noted for iron, nickel, zinc and copper (11).

An appreciable amount of zinc is usually found in leachate, 0.8 mg/l was reported for an old landfill site in Waterloo, Ontario (12, 33) and 2 mg/l in an Oceanside, California study (44). Iron and magnesium occur in variable concentrations (Fe to 25 mg/l; Mg to 81 mg/l). Selenium is often present, as it is used in most paper products (18).

The slow rate of bio-degradation of most organic refuse even after nine to twenty years (43) affects leachate composition. Rovers et al (35) showed that the release of COD, chloride and total Kjeldahl nitrogen depends on the quantity of leachate which, in turn, depends on the water present initially and added by infiltration.

Temperature appears to affect the species of bacteria, affecting COD, pH, total solids and phenolphthalein acidity (26, 28).

Decomposition appears to occur in two phases. In the initial acidifying step bacteria metabolizes fats, proteins and carbohydrates to fatty acids and simple organic acids. In the subsequent deacidifying step organic acids are converted by methane forming bacteria into methane and carbon dioxide.

Generation, composition and movement of land fill gas are also important (11). Methane increases in concentration with age of site as conditions change from aerobic to anaerobic. Hydrogen sulphide can be generated, particularly if the waste contains sulphate, such as gypsum (11).

Organic compounds are usually rapidly attenuated in the soil, as indicated by BOD, whereas some inorganic species, such as chloride, resist attenuation (2, 34, 52).

Soil materials behave like ion exchange resins with ion exchange capacities and "break-through" points, resulting in leachate attenuation until chemically saturated (34). There is also a filtering action, removing suspended solids and reducing permeability and thereby further leachate movement. Chemical precipitation and co-precipitation, gaseous exchange and microbial action can be involved (25).

There is minimum impact in the local environment if leachate is discharged into a municipal sanitary sewer system. Leachate can be recycled or contained. However, liners have not been found completely effective to date; hence location of a site in a soil with good attenuation properties is necessary.

Deep silts, clays and shales are usually preferred with limestone and gravel rarely acceptable (43). Minimum depth to the water table is important.

In Pennsylvania, some toxic industrial wastes unsuitable for incineration are only acceptable after processing to retard leaching if encapsulated in the disposal site in a relatively impermeable cell surrounded by a layer of lime or finely crushed limestone.

Industrial wastes can be made more suitable for disposal by treatments such as dewatering, mixing with a relatively inert water such as fly ash or "fixing" by proprietary processes such as "Chem-Fix" of Environmental Sciences Inc., Pittsburgh or that of Chem-Met Disposals, Wyandotte. Sulphides, calcium carbonate and gypsum are often included with organic additives.

LABORATORY TESTS

The laboratory is involved in both site selection and evaluation of solid wastes. Because of the complex nature of leachate generation and the heterogeneity of wastes, most studies have been conducted in the field in test cells (44) or by using large lysimeters in the laboratory (11, 34).

A large number of inter-related factors affect leachate compositions.

It is obviously difficult to simulate disposal site conditions in a small scale laboratory test. In order to obtain uniformity it is usual to leach with distilled water in a column or by a "shake" test but there are serious limitations necessitating considerable judgement in the interpretation and application of data.

Rovers and Farquhar studied the capacity of soil to remove contaminants by the use of sealable acrylic columns which could be filled with undisturbed soil using a Shelby tube (34). Leachate was supplied from a simulated land fill. A quick small scale test was devised by shaking soil with leachate in Erlenmeyer flasks for different lengths of time.

The use of distilled water as a leaching liquor has the advantages of excluding many unknown factors and permitting standardization. However, even for distilled water, there are large differences in solvent properties depending on whether there is

continuous contact with fresh water as in a column percolation test or if the solute is not removed, as in shake or static tests.

Another important factor is whether the sample is disturbed (shake tests) or undisturbed (column and shake test). This is not as important in finely divided intervals such as fly ash or foundry sand but becomes highly critical if the material is in hard lumps or cemented. Obtaining undisturbed samples of most material in a core is difficult, particularly in a narrow cylinder, and there is always the possibility of channeling through cracks or at the edges of the cylinder. In some instances, a bacterial slime can develop preventing flow. If lumps are pulverized there is a large increase in surface area available for leaching. Abrasion of particles can also occur during the shake test. Even drying a sample can change its leaching characteristics.

A problem with "undisturbed" samples is that it is difficult to obtain a truly representative sample unless it is large, whereas if it is pulverized and blended this difficulty is overcome.

One possibility is to leach narrow range size fractions and interpret the data based on size distribution and surface area considerations. This would permit comparison of tests and some indication of severer conditions such as the crushing of wastes during

handling operations.

With large lumps it is not possible to conduct small scale column or shaking tests. Some indication can be obtained by immersing the material in the leaching liquor under static conditions, agitated or contacted with fresh liquor through the use of a pump.

The lumps can be cut or pulverized to a certain size to permit standardization but this can change surface effects.

A rough surface, such as presented by a scoriaceous slag, provides a large surface area for solution effects.

In a landfill site conditions are very different from distilled water contact. Soluble organic compounds (usually acidic) are produced which can transport many metals as chelates. Gases such as carbon dioxide and hydrogen sulphide can react chemically, accelerating solution or precipitation. Conditions can change from aerobic to anaerobic. There can be intense micro-organic activity or minimal due to toxins introduced with the waste or developing later. Water can be in abundant supply or restricted. Leachate and gas may be retained within the site by an impermeable seal or by low porosity of the compacted waste and fill.

An attempt can be made to simulate the

internal environment of the site by leaching with weak organic solutions such as acetic acid or neutral or acidified ammonium acetate. Ethylene diamine tetra acetic acid (EDTA) can be used as a chelating agent. The use of simulated rainwater can sometimes more closely duplicate natural conditions. If present in significant concentrations in rainwater, sulphur dioxide can have a larger effect than carbon dioxide. However, in a landfill site with decaying organic refuse, carbon dioxide will have a significant role. Methane is considered to be chemically inert.

A problem with the use of simulated rain is the high variability in composition of rainfall with location a major factor. Dr. Kramer's group at McMaster University has found the rain in Hamilton to be slightly alkaline where as in Sudbury it is acidic. Attempts have been made to "simulate" rain by adding sodium bisulphite or bicarbonate. This route is not as satisfactory as bubbling carbon dioxide into water because the sodium ion may modify the properties of the material.

In some instances, analysis of the liquor associated with the solid is important with respect to disposal of the waste as it may have a larger effect on the leachate than the solid fraction.

Microbial action should not be ignored particularly if metals such as mercury or lead which can be

methyated are present in the waste. "Fixing" the metal such as in the sulphide form will retard leaching initially but in the long term there may be slow release of the methyated forms and/or chemical or bacterial conversion to the more soluble sulphate. The maintenance of an aerobic or anaerobic internal environment, nutrient supply and presence of toxins will have major effects on biological acitivity. If the waste is inter-layered with fill biological activity could be very significant.

The type of test conducted is, therefore, highly dependent on the nature of the waste, physically and chemically. It is usually advisable to perform a total chemical analysis prior to a leach test to determine what parameters are likely to be important.

Choice of leach liquor has, of course, a major effect on the concentration of ions in the leachate. This has been observed in MOE studies and in the shake test on fly ash using water and EDTA extractants reported by Theis (41). Of interest, was the high arsenic in the EDTA leachate compared with water.

LABORATORY LEACHING PROCEDURES

Environmental Sciences Inc. developed a leaching test in connection with the evaluation of Chem-Fix treated waste*. It was felt that only a steady state percolation test on relatively undisturbed material should be used to predict long term effects of leaching. The results of 400 leaching tests compared favourably with field data. Results were submitted to EPA and met with their approval in each case.

One hundred grams from a core of material is placed in a 40 x 600 mm chromatography column. Water is percolated through the column at a rate of 1 ml per minute and collected in 100 ml portions. Up to 32 cuts are collected. Each 800 mls simulates 25 inches of ground water passing through the material in the field.

The procedure has been used in industry, such as in the testing of mercury leached from "Chem-Fix" treated sludge in Thunder Bay, Ontario, in which the material was leached for the equivalent of 25 years, assuming one third of the rainfall infiltrated through the solid waste. A similar procedure was used by the Ontario Research Foundation for a foundry sand.

A shake test has been developed for leaching fly ash (48). Five hundred grams of ash are shaken with 2 litres of distilled water for 48 hours and the supernatant liquor analyzed. EDTA was also used as an

* Chemfix Division of Environmental Sciences Inc.
Leaching Tests for Solids Developed from Treatment of Industrial Wastes. Data Sheet 105. Environ. Sci. 505 McNeilly Rd., Pittsburgh, Pa. 15226.

extraction.

Shaking tests have been used for many years for measuring available nutrients for plant growth in soils analysis, using extractants such as ammonium acetate, acetic acid or EDTA, usually in a 1:4 ratio.

ONTARIO MINISTRY OF ENVIRONMENT
TEST PROCEDURES

Various procedures have been used in the MOE Central Laboratory during the past two years depending on the availability of equipment and time, sample size and characteristics and intended disposition of the waste. Attempts were made to simulate natural conditions by column percolation tests and used leaching solutions such as simulated rainwater with bisulphite, neutral and acidified (pH 4.8) ammonium acetate, acetic acid and EDTA. These have been used to determine "available" or "extractable" inorganic species in agriculture. One per cent sodium hydroxide was used as an extractant for phenols. To obtain a rapid assessment of the severity of pollutant potential a "shake" test was devised using the same extractants as for the column tests. A ratio of 1:50 was selected principally on the basis of recent laboratory experience with extractable phosphorus.

0.5 N sulfuric acid was also used to assess the effect of contact with acidic waste. Leachate was analyzed principally for heavy metals because of the limited volume available.

In the earlier MOE studies' column tests the waste sample was taken As-Is, using as much material as practicable (usually 100 gm). This was partly dictated by the need for an adequate volume and concentration of leachate for analysis. A simple constant

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head device was used for leach liquor with inverted 500 ml volumetric flasks and leach rate controlled by a screw clamp at the exit of the column. Two 500 ml cuts were usually collected, each representing 8 inches of ground water.

Some of the earlier work at the Ministry of the Environment Central Laboratory was to follow up on the leaching of "Chem-Fix" treated mercury sludge using the column percolation procedure. Biological activity was stimulated by leaching with nutrient rich water (BOD water) seeded with bacterially active river mud. The test was continued for an extended period. Conditions were partially aerobic through air bubbling into a constant head device.

The shake test involved extracting 1 gm dried pulverized waste with 50 ml leach liquor for 15 minutes on a wrist-action shaker and repeating for a second cut. Limitations of the test were recognized. Consideration was given to adopting the fly ash shake test procedure with a 1:4 solid:liquor ratio.

Recent acquisition of Technicon pump and fraction collector has permitted development of a more satisfactory percolation test. The collector has a capacity of four rows of fifty 25 ml tubes and a 30 minute timer. The pump permits controlled flow of leach liquor and gas. Four samples can be run simul-

taneously for up to 50 cuts or one sample can be run for up to 200 cuts (83 hours) with little attention. It is also possible to introduce gas at controlled flow.

Narrow plastic columns were first used with 10 to 25 grams wet weight, percolated with 1 ml per minute of leach liquor. For some materials of fine particle-size or heterogenous composition there were problems of insufficient volume of leachate, leaks, channeling or non-representativeness. A clear acrylic tube holding 500 gm or more of material (usually 6-7 in. column) was found more satisfactory. Pump tube size had adjusted to provide a flow rate at or below the permeability rate for the material or a maximum of 1 ml/min.

It was possible to obtain an indication of the volume of water needed to saturate the material before leachate flow and permeability, both important is assessing the effect of a waste on leachate production. Gas flows could also be controlled by Technicon pumps.

Since carbon dioxide appears to be the most important reactive gas in most landfills, occurring sometimes up to 50% by volume, it was decided to conduct leaching tests with distilled water, treated with carbon dioxide and either air or nitrogen. Usually air was first pumped into the column followed by nitrogen. Carbon dioxide was generated from marble chips and 6 N sulphuric acid.

Nitrogen was simply prepared by passing air through pyrogallol solution. The gases can be mixed with the water flow prior to entering the solid waste column directly or after collection in a reservoir. The pH of the distilled water/carbon dioxide/air solution remained constant at 4.7 under the conditions of the test.

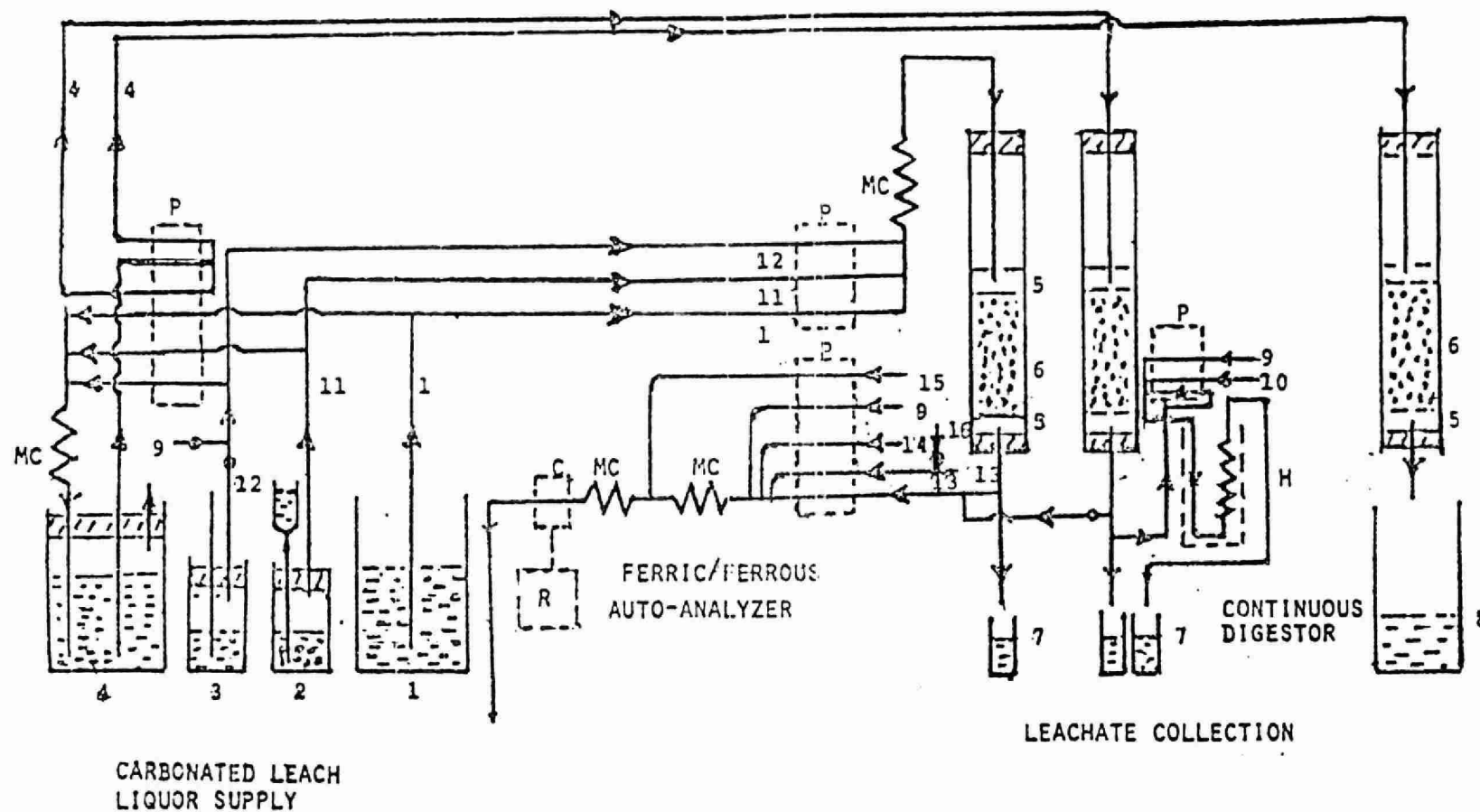
Leachate cuts are tested for pH and conductivity to help determine the frequency of testing for parameters of interest. Cuts are analysed more frequently in the region of maximum curvature in the leach curve. Where the slope is uniform and linear cuts can be composited for analyses requiring a larger volume.

Present practice, if there is sufficient material, is to set up two columns with 500 grams of the waste. The leachate from one column is not preserved for measurement of anions. Conductivity and pH are currently monitored manually; continuous monitors could be installed. The effluent is split with one stream analyzed for ferrous and total iron on a continuous or intermittent basis using a o-phenanthroline with/without hydroxylamine. The ferrous/total iron ratio is used as an estimate of Redox conditions in the column.

Leachate for the second column is treated with aqua regia at 95°C in a continuous digester for digestion and AAS analysis on selected cuts.

With the 2 in. I.D. column 51.5 ml leachate corresponds with 1 inch of water infiltrating the waste. With 1 ml/min. flow rate this corresponds with 19.5 in. infiltrating water in 50 cuts collected over 16.7 hours. If it is assumed that one third of the rainfall penetrates the mass this is equivalent to about 50 inches rainfall (about two years). With wastes of low permeability the volume of infiltrated water is less; however, the ratio of infiltration to rainwater is probably wider. Some tests are being run for over five years rainfall equivalent.

Since the presence of organic matter has a profound effect on the composition of leachate at least for some types of industrial waste, such as foundry sand, due to the formation of organo-metallic and hydroxy complexes, present practice is to follow the first phase of the test on the same waste material by replacing the distilled water with organic leach liquor. Ammonium acetate 1 N, adjusted to pH 4.8, appears to be satisfactory, particularly as this reagent has been widely used for the measurement of extractable metals. Other reagents, such as acetic acid, EDTA, natural landfill leachates or humates, will also be evaluated. Dilute sulphuric acid will be used in some instances such as in cases where the waste would come in contact with more highly acidic waste or in areas of acidic rainfall.



LEGEND

1. DISTILLED WATER OR EDTA, ETC
2. CO₂ GENERATOR (KIPPS)
3. DEOXYGENATOR (PYROGALLOL)
4. CO₂-AIR/N₂ WATER
5. GLASS WOOL
6. SOLID WASTE
7. VIALS (FRACTION COLLECTOR)

9. AIR
10. HNO₃/HCL
11. CO₂
12. N₂
13. HYDROXYLAMINE HCL
14. PHENANTHROLINE
15. BLFFER

- P PUMP-TECHNICON
- H HEATING BATH
- C COLORIMETER-TECHNICON
- R RECORDER
- MC MIXING COIL

RESULTS OF LEACH TESTS

The older version of column leach test was used for most of the earlier samples of solid waste studied at the MOE Central Laboratory, using distilled water, 2.5% acetic acid and .005 N EDTA leach liquor. A wide range of waste types were handled ranging from sugar refinery waste to foundry sand. Analyses were run chiefly for the more common heavy metals and conductivity and pH in the water extracts. BOD and COD were analyzed on organic wastes. Of interest was the high iron and aluminum in a foundry sand, even in a water extract. Concentrations were much higher in the acetic acid extract.

There were also instances of high phenols (17 mg/l) and high BOD and COD (6000- 9000 mg/l).

In the Shake Test high concentrations of aluminum were released from an alum plant mud, high manganese from a foundry waste and high chromium from a chrome sulphonator sludge.

Analysis of the water associated with the solid waste was felt to be a good indicator in a lagoon sludge and leather processing waste. High ammonia and sulphide concentrations were found in the lagoon and high total sulphur, BOD, COD and conductivity in the leather waste.

There was a wide range in pH for some leachates. Alum plant mud and foundry sand were highly acidic whereas black liquor was strongly alkaline.

Note was made of the colour of the leachate and the presence or absence of turbidity after settling. Strong amber or brown colours were produced in ammonium acetate leachate of foundry sand.

Laboratory data for some leaching tests using the older column method and the shake test for those metals released in significant amounts are given in Tables 1 and 2. Concentrations are expressed as mg/l in the leachate and as ug/g (p.p.m.) calculated back to the dry weight of material used.

It is evident from the column leach tests on filtered wastes (Table 1) that much higher concentrations of zinc and iron were released by acetic acid compared with water. EDTA was less effective, possibly because of the low concentration used. Further work will be conducted with 0.05 N EDTA, a concentration which is widely used by other workers.

In the shake tests (Table 2) it is again evident that acetic acid released much more aluminum, chromium and iron than water. Ammonium acetate had little effect, probably because it was at pH 7 rather than at pH 4.8 as used later in a column leach test on foundry sand. Acetic acid followed two 500 ml cuts of ammonium acetate with little further release of iron, zinc and manganese. Sulphuric

acid released more aluminum than acetic acid from alum plant mud, particularly from the second cut, indicating it was dissolving less soluble forms.

Unfortunately, the material used in the earlier column tests was not available for shake tests hence no direct comparison is available. The types of waste evaluated were also very different.

Only a limited amount of work has been done to date with the large acrylic columns and fraction collector system. Leaching studies are being conducted with foundry sand samples initially with distilled water mixed with carbon dioxide and air followed by carbon dioxide and nitrogen. Following prolonged leaching the water is replaced with 1 N ammonium acetate at pH 4.8.

The distilled water leachate was alkaline (pH 9 to pH 12) throughout the test for the equivalent of 80 inches of rainfall with high conductivity initially in some samples. Only trace concentrations of iron, copper and zinc were released. The leachate from one sample was initially pale brown in colour and in others there was a colloidal suspension. Changing from aerobic to anaerobic conditions (from air to nitrogen) seemed to have little effect. In some samples the change-over from distilled water to ammonium acetate was most dramatic. Leachate

colour changed to dark amber or yellowish brown and iron and manganese concentrations from under 1 mg/l to several hundred.

This study demonstrated that prolonged leaching with distilled water even acidified with carbonic acid gives no indication of the effect of organic chelates, at least for foundry sand wastes. It may give some indication of leachate which could result from exposure only to normal rain water. If this type of material is to be disposed of in a landfill site a carbonated distilled water leach is obviously not adequate for characterizing the environmental hazard. Search is continuing for a completely satisfactory leach procedure.

Column and shake leach tests are also planned for heat processed sewage treatment plant digested sludge and thermal generating station fly ash.

FIGURE 2

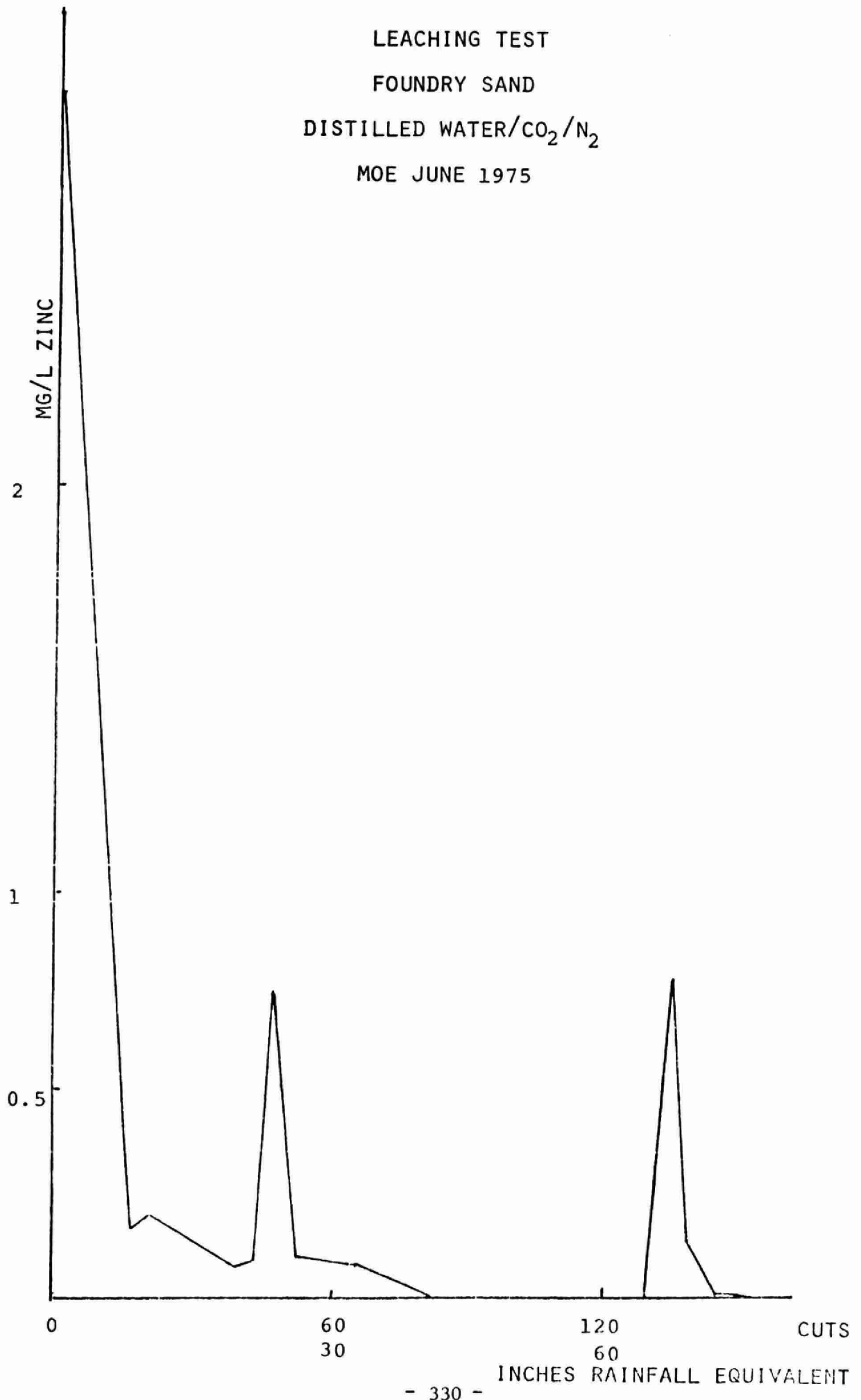


TABLE 1 CONT'D

FILTER WASTE
AUTOMOTIVETOTAL ANALYSIS DRY WT BASIS
UG/GWATER
UG/G MG/LACETIC ACID 2.5 %
UG/G MG/LEDTA .005 N
UG/G MG/LFe 45000
Zn 3890

Pb 1395

Zn 2.5 .4

Fe 9 1.4

pH 5.7

COND 290 MMHOS

Zn(1)
1953 295
(2)
748 113
(3)
232 35Fe(1)
5144 777
(2)
5925 895
(3)
2688 406Mn(1)
659 100
(2)
318 48
(3)
152 23Pb(1)
106 16
159 24
96 14

253 38

107 16

180 27

231 35

293 44

353 53

90 14

50 8

94 14

79 12
37 5.6
50 7.5

SUGAR WASTE

BOD(1) 6500
(2) 100COD(1) 8600
(2) 100pH (1) 6.4
(2) 7.2

* (1) & (2) 1ST & 2ND 500 ML CUTS, RESPECTIVELY

TABLE 1

ANALYSIS OF LEACHATES

COLUMN LEACH TEST - 100 GM WET WT/500ML

WASTE	TOTAL ANALYSIS DRY WT BASIS UG/G	WATER UG/G MG/L	ACETIC ACID 2.5 % UG/G MG/L	EDTA .005N UG/G MG/L
BULK CARRIER		PH 6.9 COND 740 MMHOS	AL(1)* 45800 1020 (2)* 15400 340 FE(1) 269 6 (2) 49 1	AL 411 9.1 FE 18 .4
PRE-COAT FILTER AUTO MNF.	ZN 5500 PB 3085 CR 899 PHENOL 7.2 PCB 0.5	ZN(1) 45 3.3 (2) 76 5.6 PB(1) 35 2.6 (2) 24 1.8 PH 11.8 COND 5800 MMHOS PHENOLS 350 PPB	ZN(1) 676 50 (2) 163 12 PB(1) 42 3.1 (2)19 1.4	ZN(1) 49 3.6 (2) 33 2.4 43 3.2 43 3.2
FILTERED SLUDGE FIBRE GLASS	AL 6870 CA 22300 FE 2175 MG 1915	COND 690 MMHOS PH 8.1 PHENOLS 17000	AL 6.6 0.6 ZN 5.4 0.5	

TABLE 2

ANALYSIS OF LEACHATES
SHAKE TEST - 1 G/ 50 ML - 15 MIN.

	TOTAL ANAL.	WATER UG/G MG/L			AMM - ACETATE IN UG/G MG/L			ACETIC ACID UG/G MG/L			SULPHURIC ACID 0.5 N UG/G MG/L			LIGUID FRACTION OF WASTE
ALUM PLANT MUD		AL(1)	965	9.3	AL(1)	33	0.7	AL(1)	1715	34	AL(1)	2365	47	
	AL 28.1 MG/G	(2)	110	2.2	(2)	31	0.6	(2)	495	9.9	(2)	1250	24	
		ZN(1)	21	0.4							FE(1)	290	6	
		(2)	4	.08							(2)	950	19	
		PH	3.4								ZN(1)	30	.6	
			4.0								(2)	27	.5	
FOUNDRY WASTE		FE	417	8.3	MN	35	0.7				MN	3000	60	
WALLEABLE IRON	MN 3500UG/G	PH	7.7-7.8											
CHROME SULPHON-		CR(1)	250	4.9	CR(1)	560	11.2	CR	5500	110				
ATOR SLUDGE	CR 7400 UG/G	(2)	19	0.4	(2)	247	5.0							
	FE 5600 UG/G	FE(1)	26.5	0.5	FE(1)	23	0.5	FE	3000	60				
		(2)	9.0	0.2	(2)	17	0.3							
		PH	7.5, 7.8											
LAGOON SLUDGE	FE 2000 UG/G	FE(1)	3.5	.07	FE	12	.2							150 MG
(LINDSAY)	H ₂ S 644 UG/G	(2)	4.0	.08	ZN	22	.4							H ₂ S 2
		PH	11.3		MN	14	.3							150 MG
LEATHER WASTE		COND	4200											NH ₃ AS 1
		MMHOS												TOTAL
														SULPHUR
														1100 MG
														BOD 2400
														COD 4000

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SOME THOUGHTS ON SCREENING, CLASSIFYING, CONVEYING

SHREDDED REFUSE

Most refuse processing facilities involve shredding and separating. No single step can separate clean recyclable paper or combustibles from the mix and hence screening and air classifying are commonly used.

The unique, new Rader Disc Screen looks promising in this regard and the Rader Air Density Separation System is operational. The screen separates by size, the ADS by flotation velocity and the light fraction is a clean, 5,000 BTU fuel.

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by

FRANK HAMILTON

Technical Director

Resource Recovery Group

Rader Pneumatics - Memphis, Tennessee



Mr. Hamilton's twelve years association with Rader has been devoted mostly to special projects involving difficult to handle materials.

He attended Northwestern University before World War II and since his release from the Army he has been involved in engineering and construction of complete processing plants and the design of special equipment involving materials handling systems. His major work areas have been in the wood using industry, such as lumber, pulp and paper, plywood and particle board, as well as the sugar cane industry and other specialized areas of concern.

AIR ENVIRONMENT REVIEW OF ASBESTOS, MERCURY AND LEAD

The potential health hazards of airborne asbestos, mercury and lead have been of increasing concern because of the possible long term deleterious effects of exposure to low concentrations of these materials. Existing ambient concentration measurements are provided for geographical areas of recent concern. As background the flow of these materials through the Canadian economy and details of the various physical and chemical forms and uses are discussed. Estimates are presented of emitted quantities by geographical area and source and include mining, manufacturing, waste disposal and inadvertent releases.

The pathways by which the materials find their way into the environment are described and quantities are provided for controlled, uncontrolled and inadvertent sources as determined from surveys, actual measurements and recent investigations in Ontario.

Presented by



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DR. EUGENE KOCZKUR assisted in
the preparation of the Paper.

Dr. Gorber obtained his Bachelor of Chemical Engineering in 1966, from the University of New Brunswick, and his Doctorate in 1973 from the University of Waterloo. He has worked with James F. MacLaren Limited, since 1971, in the field of air and water pollution. He is currently Manager of the Water Treatment and Waste Disposal Division.

the pressure to clean up the air made it even more attractive to utilize this material in more meaningful ways. So today virtually all of the fibre that is brought out of the woods is being used; in pulp for paper and paperboard, building products such as wallboard and particle board, core stock to be laminated with fine veneers for furniture and doors, etc. Also what can't find its way into a product, now finds its way into steam generation boilers. This fuel is often prepared bark, sanderdust and the like.

So, its a bit natural that Rader should find itself in this extension of the industrial refuse industry. We are also very much involved in the municipal refuse aspects of solid waste as well and feel that there is likely to be a marriage of sorts between the two. There has already been interest by a number of industrial plants that generate their own steam in coal fired boilers to substitute prepared municipal refuse as fuel. The ever increasing cost of energy fuels is creating a market place for this new -- old -- neglected resource. There is also in the planning stages at least one industrial complex that is talking about a 100% refuse fired steam generating unit to burn in house as well as municipal and commercial refuse fuel.

SLIDE NO 1. So with a few words let's show what Rader has done and is doing in the total solid waste field as it relates to municipalities, commercial and industrial complexes and the like. The slides you will see are from the St. Louis installation for the most part and this is the only full scale Air Classifier in full time use today. We have ready for start-up in July, the ADS System at the City of Ames, Iowa, also for municipal refuse. By September, we will be starting up the ADS System for General Motors Truck and Coach Division at Pontiac, Michigan. This will be in house generated solid waste as well as some brought in from other plants. A great deal of this will be packaging received in large quantity from their various suppliers and furnishers of components. The configuration of the ADS System is very similar whether it is used on industrial, commercial or municipal solid waste.

SLIDE NO. 2. This is a general view of the installation at the City's processing facility in St. Louis. Back in November of '73, when we first pushed the buttons on this system, we were totally committed to take whatever they could pour through their 1250 H.P. shredder. There was no way to bypass the process. And, the normal process rate through the shredder was 45 tons per hour. It was going to work or else and none of us like the alternative.

SLIDE NO. 3. We have had many visitors to the St. Louis facility, literally thousands. The general flow plan for this is shown here in "schematic" form. This plant is a single grind system to a 1-1/2" minus particle size -- air classified to extract the cleanest possible "light fraction" -- the fuel for a suspension fired boiler without grates and a willingness to accept some degree of fibre in the heavy fraction. At this plant the ferrous fraction is removed from the "heavy" stream that has dropped out of the separation chamber and this is transferred to an Eidel "Nugetizer" to densify the ferrous fraction to an acceptable bulk density for use in an electric furnace.

SLIDE NO. 4. Another schematic showing the air classifier -- note the unusually shaped surge bin at the beginning of the system.

SLIDE NO. 5. The covered belt conveyor on the left is the original transfer conveyor from the shredder to the Miller-Hofft storage bin. It was the original intention in this plant to burn the whole garbage and only get the ferrous out of the fuel. Because lots of problems developed, a means of removing as much as possible of the other non-combustible was sought and it has to be inserted in the middle of the conveyor without a by-pass -- (I tried my darndest to talk them into a by-pass rather than totally commit, but their ideas prevailed. They said if it didn't work they didn't want the fuel any way.)

The belt conveyor was interrupted so that the material coming from the shredder ended up in the unusually shaped surge bin. While not everyone was in agreement on the need for this bin, Rader decided it was an absolute necessity and, if some-

one insisted otherwise, we would not install the system.

SLIDE NO. 6. This slide shows the discharge end of the surge bin metering conveyor and transfer to the infeed airlock of the ADS System. At this installation, as is true at the City of Ames and also General Motors Truck and Coach Division, this transfer consists of a vibrating pan feeder. The one at St. Louis and at G.M. has a short 2' - 0" long perforated plate to get a bit of the pulverized glass and rock out of the fuel. At Ames, virtually the whole bottom is perforated with a step-down "water fall" effect to try to turn over the top layers to a second perforated section.

SLIDE NO. 7. But this transfer arrangement is in the throws of change. This whole process is in an evolutionary stage and we are learning new do's and don'ts all the time. One thing we won't compromise and that is the ability and absolute need to volumetrically control what we are putting into the system. Incidentally, you can get an idea of the size of the system components as compared to the man standing alongside the airlock.

SLIDE NO. 8. An "in-shop" photo of the ADS infeed airlock.

SLIDE NO. 9. A view of the material conveying pipeline with a replaceable back elbow, the ADS cyclone and support tower. This tower is exceptionally high and it was necessary because the light fuel fraction was deposited on the belt conveyor going up to the storage bin.

SLIDE NO. 10. A view from the top looking back down the belt conveyor showing the chute and ADS discharge airlock which puts the light fuel fraction on the belt going to the storage bin.

SLIDE NO. 11. The ADS discharge airlock at the shop, just to give you an idea of the size.

SLIDE NO. 12. This is a view of the blower (exhauster) of the ADS System. It has a 200 hp motor connected. Any of you who have seen this installation in operation will undoubtedly recall seeing emissions coming from the fan discharge. When this project was designed, we advised the City of St. Louis that the need for a filter on the air exhaust was just about

a lead pipe cinch. They opted to go without initially because no one knew if this set-up was going to work or not.

Now we include a bag type filter between the ADS cyclone and the exhauster. And because of the nature of the material that is carried through the cyclone, we are very particular as to what goes in there. We cannot afford to qualify the success of the ADS System because of a filter malfunction.

SLIDE NO. 14. This is a cross sectional representation of the ADS infeed airlock and separation chamber. We feed a metered amount of material into the airlock from the surge bin. The material is evenly distributed from one end to the other of the airlock regardless of rotor length so that we present as even a load as possible into the rising air stream.

The upward rising air current is set for a certain velocity. This velocity can be adjusted by varying the volume of air asked for by the system or, with a constant volume, by varying the cross sectional area in the separation chamber. In either case, the real meat of the coconut is that virtually all the air is coming from one place, the bottom of the separation chamber.

SLIDE NO. 15. This is a view looking up into the separation zone. This is where all the action is.

SLIDE NO. 17. This shows what is dropping out of the separation zone. We touched on screening a ways back and pointed out that we had used perforated pan and, incidentally, relieved holes in the vibrating feeder and were able to get some of the glass and grit out of the shredded refuse.

SLIDE NO. 26. We have developed, primarily for the wood using industries, what we call the Rader Disc Screen. This unit has a series of shafts with star-shaped discs mounted thereon, a certain number of discs per shaft as required for the job it is to do. The shafts are mounted with a predetermined center to center dimension so that the discs on one shaft interface with discs on the following shafts, etc. -- all running in the same direction.

SLIDE NO. 27. We have at our test facility in Portland,

Oregon, run a series of tests using a coarse grind (6" minus) refuse to see if this type of screening is suitable for getting glass and other abrasive particles out of the light fraction. The tests run so far would indicate that we are able to get 75% to 80% of the glass, sand, etc., out of the furnish along with a quantity of light fuel type fraction that is already down to an acceptable size for burning in a suspension or other type furnace. We further tested with a finer set machine and we were able to recover the fibre (most of it) and let the glass and other heavies go onward to further processing. The fibre was returned to the fraction.

We also want to talk briefly about pneumatic conveying systems for shredded refuse. We have five such systems at Union Electric's Meramec plant on basically municipal refuse. We have six such systems at Eastman Kodak in Rochester, N.Y., four of these on shredded industrial refuse, two on classifier sludge that has been dewatered on a vacuum filter. These are what we call "high pressure" conveying systems which is a misnomer in a sense that the high pressure is only high relative to a fan type system -- i.e., low pressure systems generally deal in a few inches water gauge and relatively large volumes of air. High pressure systems may deal in ranges up to 8 or 9 PSIG (not that high in refuse) and use relatively little air.

SLIDE NO. 24. This slide represents an infeed airlock which is attached to a "Tee Injector" (the transition to the conveying pipeline) which in this case has the Rader patented Scrap-Trap Tee feature. The scrap trap is most often used in the wood fibre industry for "capturing" the occasional rock or other foreign item that may get into a supply of screened wood chips or other wood fibre. We used it experimentally on one of the systems at U.E. Meramec with an astounding degree of success -- so much so that the scrap trap filled up almost immediately. The result of this is a further development for getting out additional glass and other heavy particles on a continuous and automatic basis.

SLIDE NO. 25. The feeder and tee with the manual clean-out door on the scrap trap shown here is the unit most often used in the wood fibre industry.

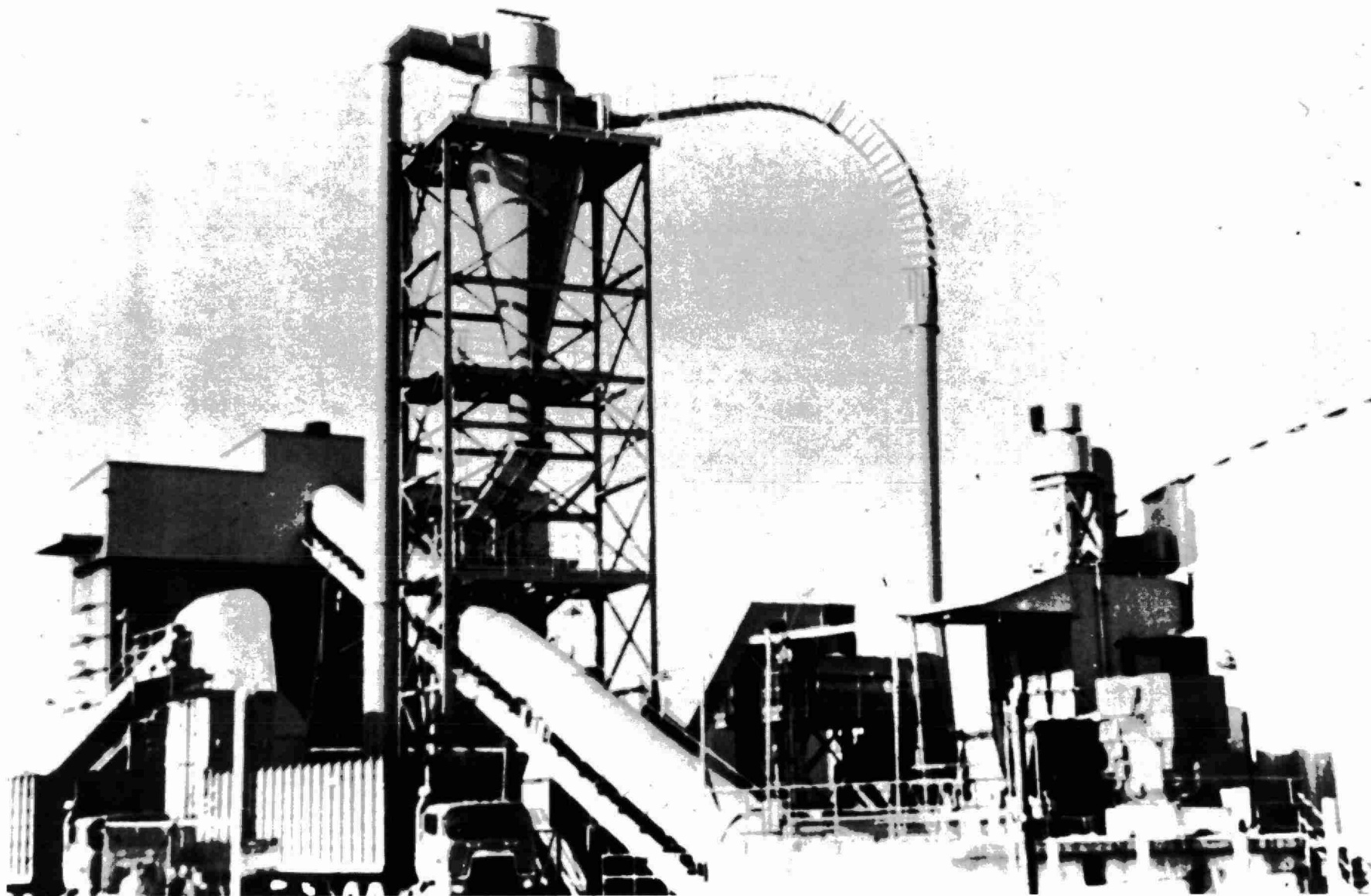
SLIDE NO. 22. Most often, when system size and capacity is thought of, it is done so in tons per hour. And, naturally so. The material is transported in trucks and weighed and is often charged by the ton on a drop charge basis. So, it's really easy to keep this system and no one has to think too much.

But really, when you have a container of material and it's full, and it doesn't care if it's dry or wet, or what kind of stuff it is that makes up the whole, you also have a volume consideration that can vary considerably in weight.

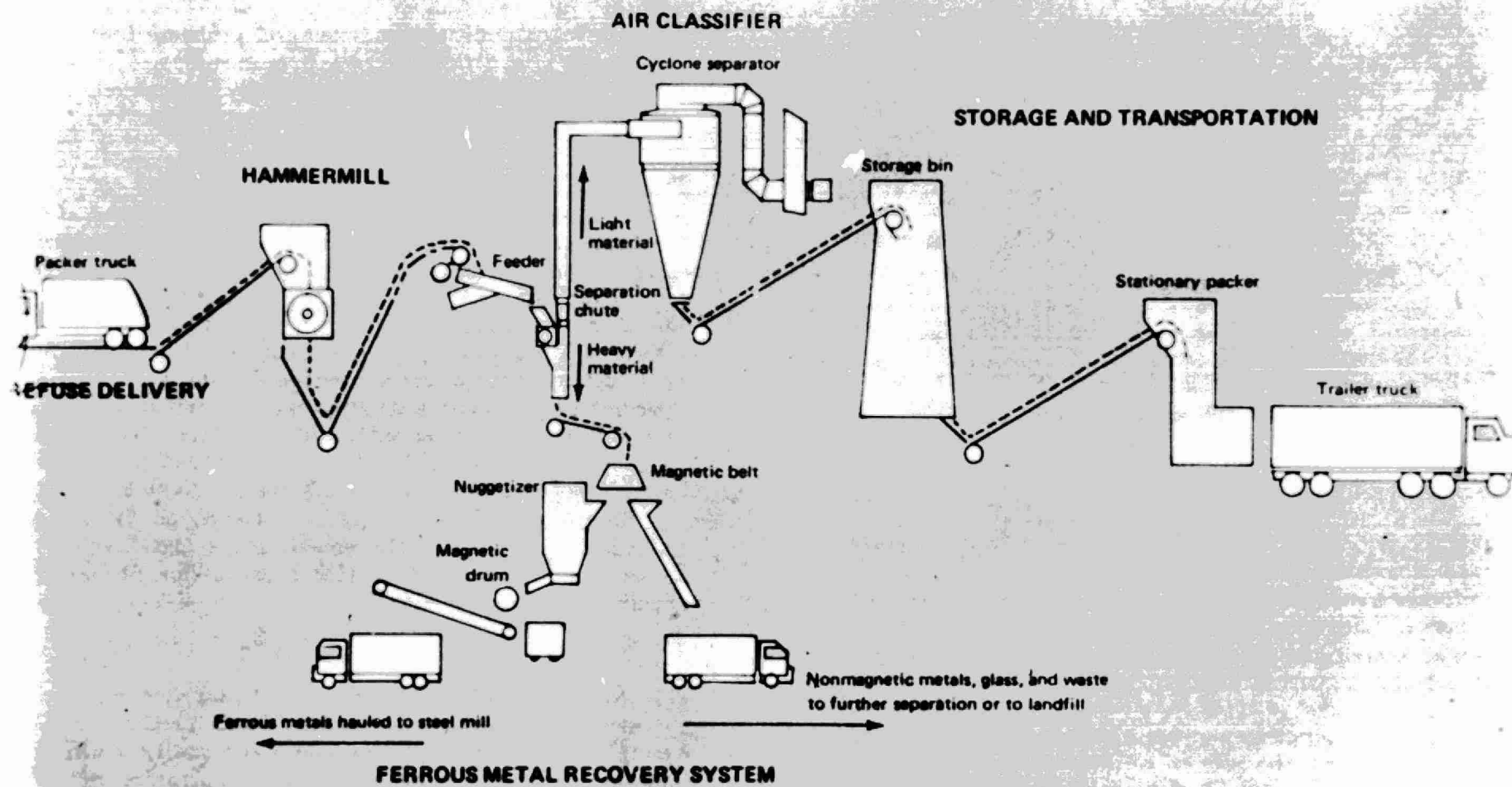
We know that this material must be handled volumetrically, and, because it can change in weight quite quickly we must design for "X" cubic feet per hour at "Y" lbs. per cubic feet. This way we can rely upon the system to do what it was designed to do. And, by knowing what the worst material is going to be, we design our velocities and power requirements around that aspect also.

So, what we like to think is this -- whether it be for conveying, classifying or screening, control of the volume of material introduced to the process is of primary importance.

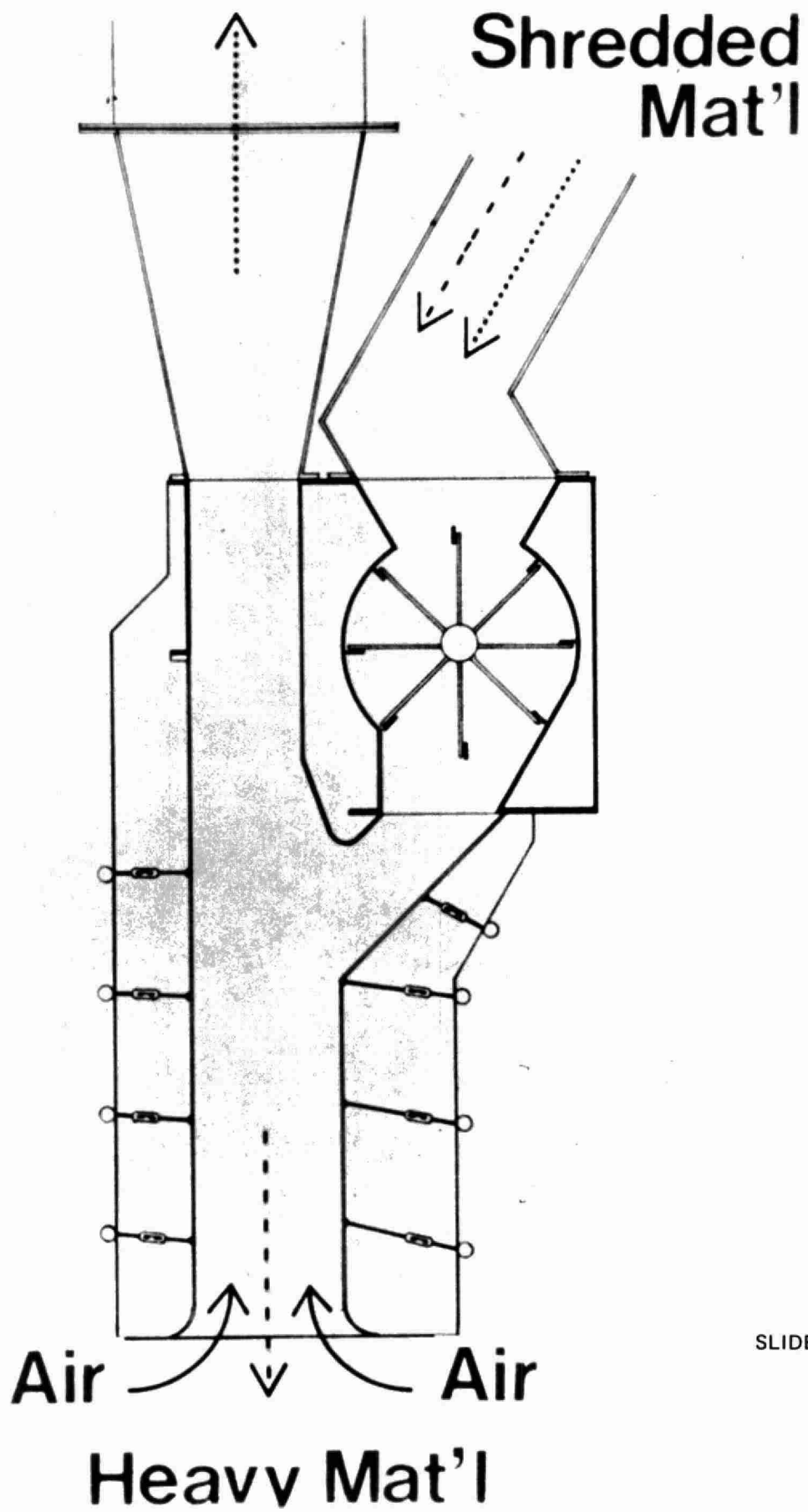
Thank you for your kind attention. I hope that some of what has been said here is applicable to some of the problems and opportunities that face our world today. For whether we like it or not, we have an ever growing stream of solid waste in all avenues of life. And while we will make some headway, hopefully, in reducing the volume per unit of measure that we consume, the units will continue to increase and we shall still have a large volume of material to do something with -- and hopefully -- constructively.



SLIDE 2



SLIDE 3

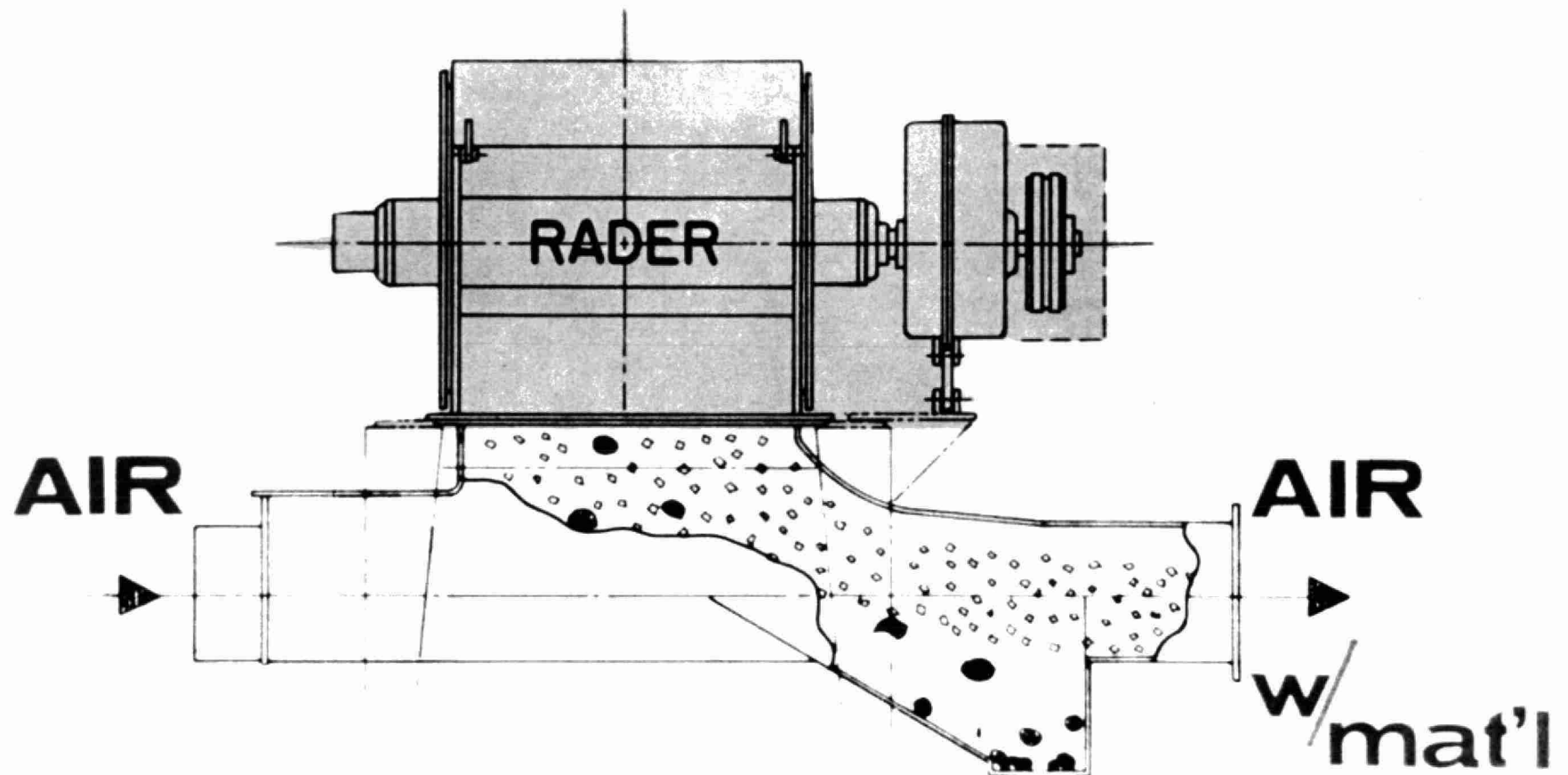


SLIDE 14



SLIDE 27

Scrap Trap Tee



SLIDE 24

ADS SYSTEM CAPACITIES

MODELS	34	50	72	100	130	160
Volume ft ³ /hr m ³ /hr	3450 100	5000 140	7250 200	10,000 280	13,000 370	16,000 450
Tons/hr nominal metric maximum metric	12 11 19 17	17 15 27 24	25 23 40 36	35 32 55 50	45 41 72 65	56 51 88 80

SLIDE 22

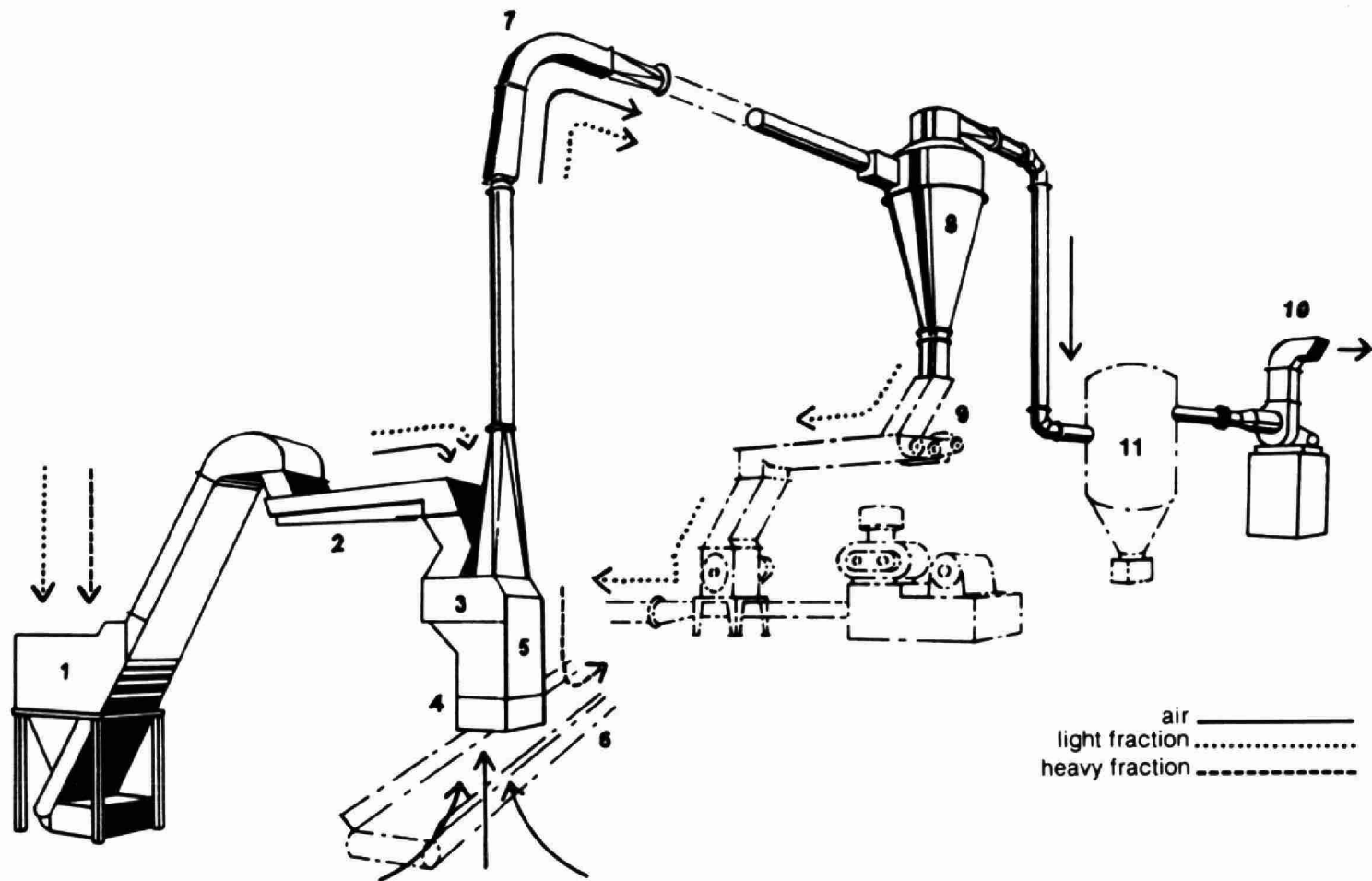


FIGURE 1

- 1-Metering bin has steeply-sloped conveyor which deposits shredded garbage on vibrating feeder.
- 2-Vibrating feeder further evens material and screens out much glass, sand and dirt
- 3-Infeed airlock feeds material into separation zone
- 4-Adjustable separation chamber helps provide controlled velocity so that light fraction is air-lifted up pipe and dense fraction is dropped out.
- 5>Action in separation chamber shows direction change of the combustible light fraction, and heavy materials falling out.
- 6-Heavy materials drop through onto belt conveyor.

- 7-Elbow with replaceable back.
- 8-Cyclone with replaceable liners separates light, combustible fraction from conveying air.
- 9-Discharge airlock in photo deposits light fraction—the fuel—on belt conveyor to storage. The Rader Pneumatic "onward" transport system in drawing has auger assembly feeding high pressure airlock.
- 10-Blower with adjustable, automatic, constant-volume control system draws air from separation zone.
- 11-Air cleaning device is shown on drawing only, and may be required to control quality of discharge air in some installations.

air —————
light fraction
heavy fraction - - - - -

EXPERIMENTAL BURNING OF WASTE OIL
AS A FUEL IN CEMENT MANUFACTURE

An experimental program was carried out at the St. Lawrence Cement Company Limited, Mississauga, Ontario, in which 330,000 gallons of used lubricating oil was burned as a portion of the total fuel requirement for a dry-process cement kiln. The system tested uses a dual four-stage preheater with a by-pass system. The oil was primarily composed of automotive crankcase drainings and contained approximately 0.6 per cent lead, 0.15 per cent bromine, 0.1 per cent zinc and 0.1 per cent phosphorus.

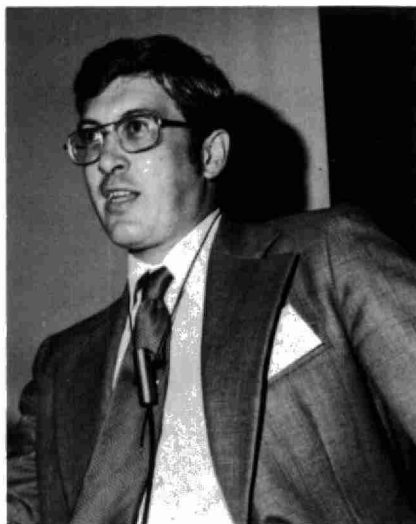
Lead, zinc and phosphorus emissions in the kiln exhaust gases were not found to be increased during waste-oil burning. A small reduction in particulate emissions and a small increase in bromide emissions was found to occur during the waste oil burn.

Presented by

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He worked in the Laboratory of the International Nickel Company for four years prior to joining St. Lawrence Cement Company. During his twelve years with St. Lawrence Cement, he has worked in various capacities: as Laboratory Assistant, Research Scientist and Plant Chemist. This past year he has been Chief Chemist for the Company.

UTILIZATION OF WASTE OILS AS FUEL IN THE CEMENT INDUSTRY

by

L. P. MacDonald
(St. Lawrence Cement Co.)

E. E. Berry
(Ontario Research Foundation)

BACKGROUND

Each year in Canada, approximately 80 million gallons of waste lubricating oils require disposal. Of this quantity, some 41 million gallons are used automotive oils. They contain both the organometallic additives included in the original lubricating oils and quantities of lead and bromine accumulated from gasoline combustion products.

Current disposal methods are generally poor with regard to both environmental and resource conservation considerations. Re-refining (recycling) back to a lube-oil stock is economically marginal and is declining in North America generally. Canadian re-refining plants currently handle from 5 to 6 million gallons per year. Additionally, the acid-clay treatment process usually employed produces a significant amount of sludge which itself represents a disposal problem. More economically attractive, road oiling is the most widespread disposal method currently used. However, in addition to being a wasteful use of an energy resource, it has been shown that (1) as little as 1% of the oil applied to the road stays to control dust. The remainder is lost to the surrounding environment. Use of this oil in conventional oil burning boilers and furnaces results in a high proportion of the lead being emitted. The quantity of oil disposed of in other unacceptable methods such as dumping directly into sewers is impossible to ascertain.

It has been known for some years that a cement kiln can act as a 'trap' for many potential pollutants. Prior to 1974, St. Lawrence Cement had conducted some inconclusive but promising studies of this aspect of burning waste oil. It was within this framework that the St. Lawrence Cement Co. and Ontario Research Foundation entered a major study in co-operation with Environment Canada and the Ontario Ministry of the Environment.

Cement Production

Cement is produced by grinding (and normally intergrinding) sources of lime, silica, alumina and iron within fairly stringent specifications of chemical composition. A normal mix (raw meal) contains approximately

76% CaCO_3 . In the kiln this mixture is burned by increase of temperature from ambient to around 2650°F . As the temperature increases, the raw meal is dried, calcined and then goes through a series of complex reactions in which the lime forms four main compounds with the other components. This burned material, called clinker, is then interground with gypsum to the required fineness to form finished Portland cement.

The (rotary) cement kiln is essentially a slowly rotating, inclined cylinder. Raw meal is fed to the kiln at the upper end and clinker leaves at the lower end where the flame brings the material up to maximum temperature. Cement manufacturing may be carried out by wet or dry-processing in either straight kilns or kilns which include various forms of preheater systems. The St. Lawrence Cement kiln used for this study is a dual, four-stage suspension preheater type with a by-pass.

The operation of a suspension preheater is illustrated schematically in figure 1. Raw meal is introduced into the duct between the first and second stage cyclones. It is swept with the hot exhaust gas into the uppermost (stage I) cyclones where gas and material are separated. The raw feed material from the stage I cyclone drops into the duct between the second and third stage cyclones and is again suspended and separated. This procedure is repeated in stages III and IV before the partially calcined feed enters the kiln. In the process of passing through these four stages, the raw meal is heated from about 150°F to about 1450°F .

The lime formed by calcination of the raw meal in the kiln effectively absorbs various elements from the combustion and reaction gases. This has been shown in particular for sulphur (2). As with any solid gas-scrubbing procedure, the effectiveness of the removal is a function of the degree of mixing between the solids and the gases.

Volatile constituents (for example KCl and NaCl) in the raw materials and fuels are removed from the solid phases in the hottest zones of the kiln. In a straight kiln these alkali chlorides condense in the cooler

regions as minute particles, and are removed from the gas stream by precipitators. Due to the intimate mixing of gases and raw material in the preheater, most of the alkali chlorides condense on incoming raw meal particles and are therefore trapped between the flame and the preheater. This circulation within the gas stream concentrates the alkali chlorides in the gas phase which can cause the preheater to plug. To reduce the alkali chloride build-up, a by-pass is included in the system. The by-pass acts as a vent to bleed off some of the kiln gases rich in alkali chloride. These are passed through a conditioning tower which cools and humidifies the gases to the optimum for precipitator operation. At the same time, the gas velocity is reduced in the conditioning tower which causes coarser material to drop out of the gas stream. The coarse material contains less alkali chloride than the rest of the material removed by the by-pass and is returned to the system through the raw meal silos.

The gases from the conditioning tower go to the by-pass precipitator and are vented by a stack to the atmosphere. The dust collected in the by-pass precipitator which is rich in alkali chloride is pelletized and discarded.

EXPERIMENTAL

The purpose of this experimental burn was to determine whether used oil could be employed as a fuel in the cement kiln without the adverse environmental effects posed by other disposal methods.

Table 1 shows the elements most commonly found as contaminants in used oils (3). It was realised that it would be futile to attempt to determine the contribution to the process by elements present in large quantities in cement raw materials or by elements present in waste oils at very low concentrations. The elements remaining after such consideration were therefore lead, bromine, zinc and phosphorus.

The emissions from the three stacks were of prime concern. These stacks exhaust the by-pass precipitator gases and the gases from the

precipitators for the two preheaters. Particulate material was collected by ORF in accordance with both Environment Protection Service (4) and Ontario Ministry of the Environment source testing codes (5). After determining the quantities of particulate collected, samples were analyzed for the four elements under study.

As a backup to the emission analyses, a mass balance over the process was made for the same four elements.

The experiment was carried out under full normal operating conditions, the only change in procedure was the introduction of waste-oil as a fuel. Normally three separate oil burners each capable of supplying 14 IGPM of No. 6 oil are used to fuel the kiln. For the experiment, one of these burners was converted to supply used oil. Through viscosity and pressure changes, it was possible to input better than 15 IGPM of waste oil.

RESULTS

The mean emission rates given in Table 2 indicate that the only significant increase in emissions during waste oil burning was with bromine, presumably as alkali bromide. A slight increase in concentration of lead in the emission particulate was noted. This is not apparent in the reporting of total emissions since the actual particulate emissions decreased during this period, possibly because of water in the waste oil improving the precipitator efficiencies. No effect of waste oil burning on zinc and phosphorus emissions (except as related to total particulate decrease) was found. This is to be expected since the percentage of these elements input via waste oil compared to the amount input via raw meal is small.

In the accumulated mass balance (Table 3), it can be seen that practically all the phosphorus and zinc remains with the clinker. The lead stays essentially with the clinker although a small amount goes to the by-pass precipitator. A large portion of bromine goes to the precipitator dust. This is analogous to the reactions of chlorine described earlier in this paper. Alkali chlorides and bromides are volatile at kiln

temperatures and are removed mainly through the by-pass. This volatility also explains the slightly higher emissions encountered during waste oil burning.

The results of the mass balance go a long way in confirming the emissions testing. We have confirmed that zinc and phosphorus are almost exclusively retained in the clinker. Lead is retained to a large extent in the clinker and bromine is partly retained in the clinker and partly collected in the by-pass dust. It should be realized that in this study we were dealing with low concentrations of elements in a large quantity of material. The raw meal for example is fed to the system at approximately 5000 TPD and an error of 0.0001% in the analysis yields an error of 10 lb/day for that element. Thus, no attempt should be made to equate small material balance losses with true losses from the process. An idea of the overall retention and disposition of each element can however be gained from the mass balance.

DISCUSSION

What is important in the present study is a comparison with other available methods of disposal of used oil. Methods such as disposal into sewers or road oiling do nothing to eliminate the hazard of potential pollutants. Re-refining leaves a sludge which is itself a disposal problem. Burning in conventional oil burners releases much of the lead into the atmosphere during normal operation, the remainder is released during soot blowing (3).

One study (6) has been reported of burning used oil in coal fired boilers. It was found that much of the lead was retained in the fly ash during burning with coal, although not as high a proportion as in cement clinker.

In all of these studies, only lead emissions were recorded. A comparison of the relative proportions of lead emitted for the St. Lawrence study, two studies on oil fired boilers (Humble (3) and Shell (7)) and a study on a coal fired boiler is given in Table 4.

CONCLUSIONS

Since all other studies were concerned only with lead release, this can be the only basis of comparison for environmental aspects. The burning of used oil in a cement kiln removes from the environment a higher proportion of the lead than other means of disposal presently available.

Since cement production requires high heat input, the use of waste oil in cement kilns is attractive from an energy conservation standpoint.

Also there is a cement plant near practically every major centre in Canada and these are of course the areas where waste oil is concentrated.

Our study was on a dry process preheater kiln. In respect to removal of volatile components from kiln gases, the preheater is a more efficient scrubber than a straight kiln. It is anticipated that similar results will be obtained with other kiln systems as long as the dust collection efficiency is adequate.

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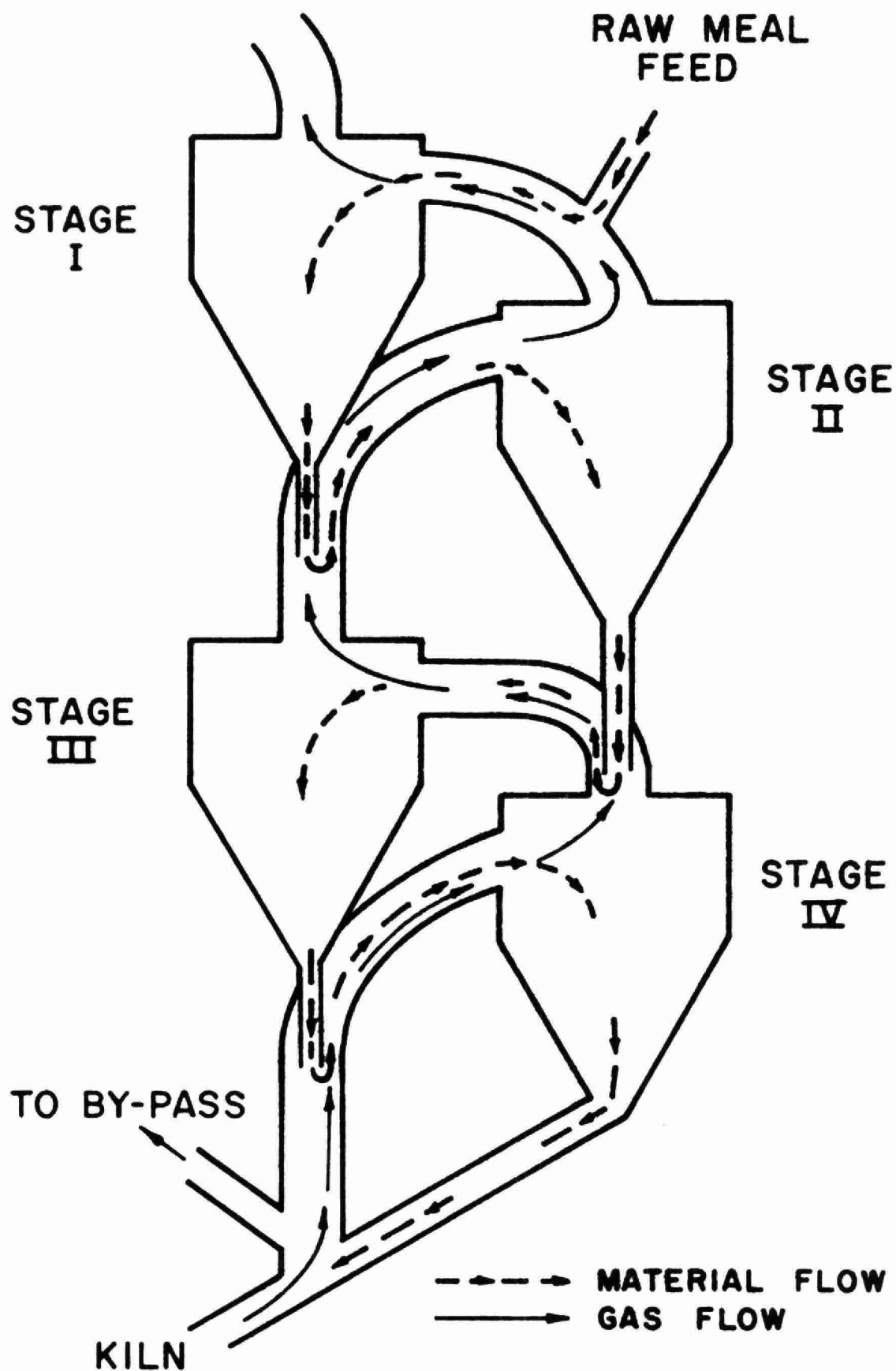


FIGURE. I. PRINCIPAL OF OPERATION OF A SUSPENSION PREHEATER.

TABLE 1

ELEMENTS FOUND AS CONTAMINANTS IN USED AUTOMOTIVE OILS (3)

<u>Element</u>	<u>Reported Concentration Range (ppm)</u>	
	<u>Min.</u>	<u>Max.</u>
Si	10	875
Ca	700	3000
Na	16	300
Fe	50	2000
Mg	10	1108
Pb	800	21700
V	3	39
Cu	5	348
Ba	10	2000
Zn	300	3000
P	500	2000
Sn	5	112
Cr	8	50
Be		6
Mn	5	10
Ni	3	30
Cd		4
Ag		1
Sr	10	30
Al	10	800
B	3	20
Mo	2	3
Ti	5	30
Br		0.15%*
S	0.21%	0.65%

* ORF/SLC Analyses

TABLE 2

AVERAGE EMISSIONS

<u>Stack</u>	<u>Test Period</u>	<u>Fuel</u>	<u>Mean Flow (DSCFM)</u>	<u>Mean Emission Rate (lb/hr)</u>				
				<u>Particulate</u>	<u>Pb</u>	<u>Zn</u>	<u>Br</u>	<u>P</u>
NW	11/3/74	No. 6	61000	73.5	.0104	.0062	.0180	.0268
NE	to		63000	38.7	.0034	.0042	.0090	.0125
SE	15/3/74		9500	3.42	.0011	0	.0210	-----
NW	22/4/74	No. 6	60000	56.6	.0067	.0060	.0561	.0178
NE	to	+	61300	25.0	.0032	.0027	.0199	.0071
SE	2/5/74	W.O.	10500	1.72	.0032	.0007	.0234	-----
NW	28/5/74	No. 6	57200	18.8	.0048	.0021	.0087	.0048
NE	to		62500	128.3	.0118	.0134	.0391	.0392
SE	30/5/74		15200	14.4	.0068	.0001	.0639	-----

TABLE 3

ACCUMULATED MASS BALANCES

Accumulation Period	Fuel **	Element	Accumulated Input (lb) (T _I)	% of T _I Derived From Waste Oil	Accumulated Retention (lb) (T _R)	% of T _I Retained in:		
						Clinker	BP Dust	Total
9/3 to 20/3	#6	Pb	502	0	627	117.1	7.8	124.9
		Br	590	0	564	55.4	40.2	95.6
		Zn	5125	0	5909	114.9	0.3	115.2
		P	40260	0	39500	98.0	0.1	98.1
17/4 to 7/5 +	#6 + WO	Pb	13731	96.6	12246	85.0	4.2	89.2
		Br	6187	52.3	4466	35.3	36.9	72.2
8/5 to 30/5	#6	Zn	22168	10.6	24526	110.6	0.2	110.8
		P	150135	1.7	147833	98.2	0.1	98.3

** #6 Indicates Bunker "C" Fuel Oil As The Only Fuel

#6 And WO Indicates Bunker "C" Fuel Oil And Waste Oil As Fuels

Table 4

Comparison of Lead Emissions During Waste-oil Burning
at St. Lawrence Cement with Conventional Combustion

Test Location	Sample Identification	Pb (lb/hr)		Out In (%)
		Total In	Total Out	
St. Lawrence Cement	22/4	45	0.014	.031
	23/4	42	0.013	.031
	30/4(1)	32	0.009	.029
	30/4(2)	32	0.012	.037
	1/5	32	0.017	.052
Humble, Baltimore Terminal (3)	15/8/72(1)	0.235	.104	44.8
	15/8/72(2)	0.235	.156	66.4
	18/9/72	0.227	.160	70.5
	22/9/72	1.17	.504	45.1
	23/9/72	1.17	.389	33.2
	6/9/72	1.14	.400	35.1
	8/9/72	0.914	.424	46.4
	11/9/72	0.933	.480	51.4
	13/9/72	1.05	.496	47.2
	11/10/72	3.77	.806	21.4
	17/10/72	3.11	.746	24.0
	18/10/72	3.57	.849	23.8
Shell Oil (7)	1	22.6	7.75	34
	2	22.6	7.50	33
	3	22.6	6.26	28
	4	17.0	4.35	26
	5	17.0	3.40	20
	6	17.0	4.02	24
	7	17.0	3.67	22
	8	9.2	4.50	49
	9	9.2	3.83	42
	10	9.2	9.73	102*
Northern States Power Company (coal-fired)	12/6/73	4.19	<.007	0.167

* Included 3 min. soot blower operation

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